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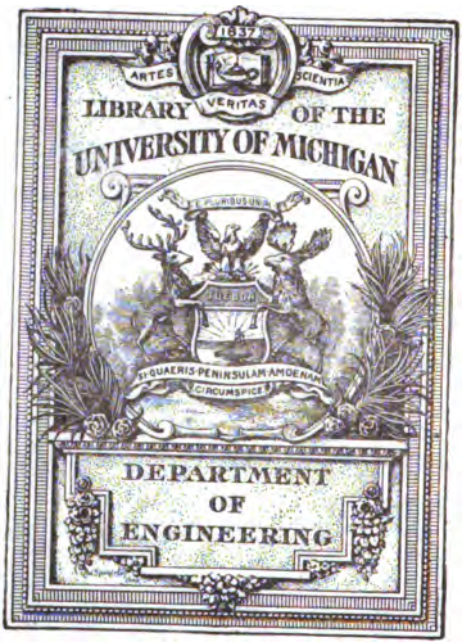
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TEXT-BOOK

OF

ORDNANCE AND GUNNERY

(SECOND EDITION)

1905

TEXT-BOOK

OF

ORDNANCE AND GUNNERY

(SECOND EDITION)

REVISED AND ARRANGED FOR THE USE OF MIDSHIPMEN AT THE U. S. NAVAL ACADEMY

BY

Commander WILLIAM F. FULLAM, U. S. Navy

AND

Lieutenant THOMAS C. HART, U. S. Navy

ANNAPOLIS, MD.
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PREFACE TO FIRST EDITION

The last edition of Ingersoll's Text-Book of Ordnance and Gunnery (which has been the standard in the Navy for many years) having been exhausted, and the author not being in a position to revise the work, this volume has been prepared to meet the demands of the Naval Academy, as well as the service at large.

In preparing this work, Ingersoll's Text-Book and various official and standard publications have been consulted, and, with a view to bringing the book as nearly up to date as possible, only modern service materials and methods have been described in full.

Chapter I, on "Metals, Gun Forgings, and Manufacture of Armor Plate," was prepared with the assistance of Lieutenant Henry F. Bryan, U. S. Navy, Inspector of Ordnance. The plates and some of the data for this chapter were obtained through the courtesy of Edward M. McIlvain, Esq., President of the Bethlehem Steel Company.

Chapters XXIV, on "Gunpowder," and XXXI, on "The Proving Ground," were prepared by Lieutenant Joseph Strauss, U. S. Navy.

Chapters XXIX and XXX, on "Armor Protection for Ships and Guns," and "Penetration of Projectiles," respectively, were prepared by Lieutenant Cleland Davis, U. S. Navy.

Chapter XXXIV, on "Practical Naval Gunnery," was prepared by Lieutenant-Commander William S. Sims, U. S. Navy, and Lieutenant Ridley McLean, U. S. Navy.

The official publications and pamphlets issued by the Bureau of Ordnance and edited by Lieutenant F. K. Hill, U. S. Navy, and Lieutenant William C. Watts, U. S. Navy, have been freely consulted with the permission of the Bureau, and the editors are indebted to Lieutenants V. O. Chase and F. K. Hill, of the Bureau of Ordnance, for much valuable information and assistance.

The following named officers, on duty at the Washington Navy Yard, have greatly assisted the editors by furnishing material and

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all necessary information relating to the most recent work at the Naval Gun Factory:

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Lieutenant Horace W. Jones, U. S. Navy.

Lieutenant William D. MacDougall, U. S. Navy.

Lieutenant Joseph W. Graeme, U. S. Navy.

Lieutenant Willis McDowell, U. S. Navy.

Lieutenant Victor S. Houston, U. S. Navy.

The Naval Institute Proceedings, the Publications of the Office of Naval Intelligence, and the articles on Ordnance, by Professor P. R. Alger, U. S. Navy, have also been consulted.

WM. F. FULLAM,
Comdr., U. S. Navy.

T. C. HART,
Lieutenant, U. S. Navy.

NAVAL ACADEMY,
Annapolis, Md., October, 1903.

PREFACE TO SECOND EDITION

The first edition of this book being exhausted, this second edition has been prepared to meet immediate needs.

All chapters have been carefully scanned with a view to keeping them up to date. Changes in Naval Ordnance are being made constantly, and it is well nigh impossible to keep pace with them in publications of this kind.

The chapter on The Construction of Naval Guns has been revised by Lieutenant Byron A. Long, U. S. Navy.

The chapter on Fuses, and that on Primers, Exploders, Cartridge Cases, Powder-Bags, etc., have been revised by Ensign Harold E. Cook, U. S. Navy.

The chapter on Projectiles has been revised by Lieutenant John Halligan, U. S. Navy.

The original authors of other chapters have also revised their work.

Lieutenant-Commander A. C. Dieffenbach, Lieutenant N. C. Twining, Lieutenant John Halligan, Lieutenant Joseph W. Graeme, and Ensign Harold E. Cook have rendered valuable assistance in the revision of this book.

Mr. A. M. Elwell, of the Ordnance Office, Navy Yard, Washington, has greatly aided the editors in providing plates for this edition.

Various articles by Professor P. R. Alger, U. S. Navy, published in the *Proceedings of the U. S. Naval Institute,* have been freely quoted.

W. F. F.
T. C. H.

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CHAPTER I.

METALLURGY, GUN FORGINGS, AND STEEL FOR ARMOR.*

The Qualities of Gun Metals.

1. Definitions.—(1) *Stress.*—The term stress is used to denote the system of forces which act to produce alterations of figure and volume of a solid and of its parts.

(2) *Strain.*—In technical literature, the term strain is sometimes used to denote stress, and sometimes the change of shape caused by the stress. Here it will always be used in the latter sense; that is, to denote the change of shape caused by the stress.

(3) *Fracture* of a solid occurs when, under the action of a stress, a strain is carried so far as to cause actual division of the solid into parts.

(4) *Kinds of Strain.*—To each kind of stress there corresponds a kind of strain, as follows: For longitudinal stress we have a strain either of extension or compression; and, if the strain is carried far enough, a fracture will occur by tearing, in the former case, and by crushing or cleaving in the latter case. For transverse stress we have the strains of distortion, torsion, and bending, which, if carried far enough, produce fractures by shearing, wrenching, and breaking across, respectively.

2. Physical properties of metals.—Metals have certain properties, which are of great importance in the case of metals used in gun construction. These principal properties are *malleability, ductility, hardness, toughness, tensile strength,* and *elasticity.*

* In revising this chapter the editors were greatly indebted to Lieutenant Henry F. Bryan, U. S. Navy, Inspector of Ordnance, for assistance and information. Acknowledgment is also due to President E. M. McIlvain and the officials of the Bethlehem Steel Company for details and drawings.

(1) *Malleability.*—A metal is said to be malleable when it may be permanently extended in all directions without rupture, by pressure (as in rolling) or by impact (as in hammering).

(2) *Ductility.*—A metal is ductile when it may be extended permanently by traction, as in wire drawing. Only malleable metals are ductile, but their ductility is not necessarily in the same ratio as their malleability.

(3) *Hardness.*—A metal is said to be *soft* when it yields readily to compression without fracture, and does not return to its original form on the removal of the compressive stress; and on the other hand, a metal is said to be hard when it does not yield readily to compression; that is, when the ratio of the compressive stress to the permanent strain produced is very great. The terms *hardness* and *softness,* however, are only comparative when used in describing metals; thus we have hard and soft leads, while any sort of lead is soft as compared with wrought iron, which latter is called soft when compared with cast iron.

(4) **Toughness* in a metal is a relative term to express the power of resisting fracture by bending or torsion, and is measured by the number of times to which a definite section of the metal can be bent through a certain angle on either side of the perpendicular without any fracture.

(5) *Tensile Strength.*—The tensile strength, or ultimate strength, of a metal is the unit-stress required to produce fracture. Thus, if a bar whose cross-section is A breaks under a tensile stress P, the tensile strength of the material is $\frac{P}{A}$.

3. Elasticity, elastic strength, modulus of elasticity, set.—The *elasticity* of a metal is the property it possesses of resisting permanent deformation when subjected to a stress.

4. "† All experiment and experience agree in establishing the five following laws for cases of simple tension and compression, which may be regarded as the fundamental principles of the science of the strength of materials:

"(1) When a small stress is caused in a body, a small deforma-

* Steel and Iron, W. H. Greenwood.

† Text-book on the Mechanics of Materials, Merriman.

tion is produced; and on the removal of the stress, the body springs back to its original form. For small stresses, then, materials may be regarded as perfectly elastic.

"(2) Under small stresses the deformations are approximately proportional to the forces, or stresses, which produce them, and also approximately proportional to the length of the bar or body (Hooke's law).

"(3) When the stress is great enough, a deformation is produced which is partly permanent, that is, the body does not spring back entirely to its original form on removal of the stress. This permanent part is termed a *set.* In such cases, the deformations are not proportional to the stresses.

"(4) When the stress is greater still, the deformation rapidly increases, and the body finally ruptures.

"(5) A sudden stress, or shock, is more injurious than a steady stress, or than a stress gradually applied.

"(6) The words small and great, used in stating these laws, have very different values and limits for different kinds of materials and stresses."

5. The elastic limit of stress (sometimes called "elastic strength") is that unit-stress at which the permanent set is first visible, and within which the stress is directly proportional to the deformation. For stresses less than the elastic strength, bodies are perfectly elastic, resuming their original form on removal of the stress.

6. Elastic limit of strain.—The limit of *strain,* or deformation, within which Hooke's law holds good, is called the *elastic limit of strain* (sometimes called "elastic limit"). Beyond the elastic limit a permanent alteration of shape occurs, or, in other words, the elasticity of the metal has been impaired and a *permanent set* is produced. It is a fundamental rule for all engineering construction that materials cannot safely be strained beyond their elastic limit.

7. The coefficient of elasticity of a bar for tension, compression, or shearing, is the ratio of the unit-stress to the unit deformation (strain), provided the elastic limit of the material be not exceeded. Let S be the unit-stress, e the unit deformation, and E

the *coefficient* of elasticity. Then, by the definition, $E = \frac{S}{e}$ and $S = Ee$. By law (2) E is constant for each material, until S reaches the elastic limit. Beyond this limit e increases more rapidly than S, and the ratio is no longer constant. Since E varies inversely with e, the coefficient of elasticity may be regarded as a measure of the stiffness of the material. The stiffer the material the less is the change in length under a given stress, and the greater is E. The values of E for materials have been determined by experiments with testing machines. E is necessarily expressed in the same unit as the unit-stress. E is also called the *Modulus of Elasticity.*

8. The most necessary physical qualities of metals used in steel gun-making are great tensile strength combined with high elastic limit, toughness, and the required hardness to endure the wear in the bore due to the erosive action of the powder gases, and the friction or balloting of the projectile.

9. *Guns have been made of various metals,* principally bronze, cast iron, wrought iron, steel, and nickel steel. At the present time (March, 1903), all the high-power guns in use in the Navy are made of steel. Forgings for 12-inch, 10-inch, and 7-inch guns are now being made of nickel steel; and it is probable that nickel steel will replace steel in gun-making. Nickel steel gun-barrels have been used for the past seven or eight years for sporting fire-arms, and for Army and Navy magazine-rifles.

10. It may be stated here that the development of ordnance in this country has been intimately associated with the development of the art of manufacture of steel. It is not too much to say that the efforts of the manufacturers to excel or to keep up with the rigid requirements of the government in the production of forged and cast steel for guns, mounts, armor, and projectiles played an important part in the wonderful improvement made in recent years in the physical properties of the metal and the ability to produce large forgings and make large and homogeneous steel castings.

General Remarks on Metals.

11. As we are especially interested in the metals now used in gun-making (steel and nickel steel), only a brief mention will be made of the others:

12. Bronze, an alloy of copper and tin, is expensive, too soft for the bores of large rifled-guns, is injured by the heat of high charges, and is liable to flaws due to the segregation of its constituents. It is very ductile, is tough, but is low in elastic limit and tensile strength. It is now used for minor parts subject to no great strain, as sight brackets, hand wheels, liners to avoid the wear of steel against steel, etc. Bureau of Ordnance requirements: Tensile strength 30,000, elastic strength 13,000, elongation 25 per-cent, contraction 25 per-cent.

13. Cast iron is cheap, easily worked, but of low elastic limit and tensile strength. It can be fused and cast without difficulty, and is comparatively hard. It is not malleable, and cannot be welded, and is brittle. Castings are very uncertain in character, due to the method of manufacture. Many, apparently perfect on surface inspection, develop serious flaws in machining, and have to be rejected. Cast iron is not now used for either guns or mounts.

14. Wrought iron is almost infusible, but is readily welded. Its tensile strength and elastic limit are low; but on account of its ductility, it requires a large amount of work to extend it from its elastic limit to fracture, which makes it a comparatively safe material to use because it will give evidence of weakness before actual fracture takes place. The bores of wrought iron guns have been permanently indented or bruised by moderate firing, the metal not being hard enough. This is a serious defect under the high pressures modern guns must stand. Wrought iron is no longer used in either guns or mounts.

15. Cast steel has a higher tensile strength and elastic limit than wrought iron, but not so great a ductility. As forged steel is used exclusively in the manufacture of modern naval guns, so cast steel is used for the mounts, and it is only the ability to obtain steel castings reasonably free from dangerous flaws that has made the strong, compact, modern naval gun-mount possible. The only difference between cast steel and forged steel is that the latter has been *worked,* either by *hammering* or by *pressing,* which results in a rearrangement of the molecules and a marked improvement in the physical qualities. But it is also possible to effect considerable improvement in the physical properties of steel castings by treatment, that is to say, by annealing and tempering.

16. Forged steel combines more good qualities for use in modern guns than bronze, cast iron, wrought iron, or cast steel. It is easily fused, is malleable, and is more or less weldable, according as it is soft or hard. It is tough and elastic, with a much higher elastic limit and tensile strength than wrought iron or cast steel. Its elastic limit, or elongation within that limit, is much higher than for the other metals above noted; and this quality makes it especially suitable for gun-making, in view of the strains which are set up in guns by heavy charges. The method of manufacture, given later in detail, increases to a great degree its elastic limit and tensile strength. The manufacture of steel has been so perfected that a very uniform product is now obtainable.

Temper.

17. When steel is heated to a red heat and then suddenly cooled, for example by plunging it into cold water, we say that we *temper* it, and this operation considerably modifies the physical properties of steel. The hardness of the metal is sensibly increased, and becomes greater as the decrease of the temperature has been greater and more sudden, or as the temper has been *stronger.* The tensile strength also varies very much, but is greater or less according as the temper is weak or strong. With a weak temper, the tensile strength reaches its maximum; by increasing the strength of the temper it diminishes more and more, and finally the metal becomes as fragile as glass. The metal acquires a new property by temper—*elasticity of flexion.* This is the quality possessed by a finely-tempered steel blade of returning to its original form after having been bent under a certain force. This property is due to the presence of carbon in steel. With reference to that element alone, steel will begin to show hardness, upon being heated and plunged into water, if it contains about .40 per-cent carbon, and will get extremely hard with about .65 per-cent carbon.

18. The properties of wrought iron are not sensibly modified by temper, which is ordinarily expressed by saying that wrought iron does not temper. Pure wrought iron contains no carbon at all; commercial iron may have as much as .30 per-cent carbon. Soft or extra low steel may contain as low as .15 per-cent carbon;

there is, however, a great difference in the physical qualities of the two metals, due to the methods of manufacture. Steel proper may be said to contain from .20 per-cent to 2.00 per-cent carbon and cast iron from 2.00 per-cent to 5.00 per-cent.

19. The properties of certain cast irons are considerably modified when, after having been liquefied, they are cooled suddenly; therefore we may say, from this point of view, that cast iron takes temper like steel.

20. To state in a few words the characteristics which may serve to distinguish wrought iron, steel, and cast iron, we may say: wrought iron is forgeable, weldable, practically infusible, and *does not temper;* steel is forgeable, weldable, fusible, and takes temper; cast iron is neither forgeable nor weldable, it is relatively very fusible, and is susceptible of being tempered.

Distinctive Characteristics of Steel.

21. That which particularly distinguishes wrought iron from steel is the property possessed by the latter of receiving temper; that is, of being considerably modified by the action of temper. With a metallurgist, all metal with an iron base which is forgeable and capable of being tempered, is steel; if it cannot be tempered, it is simply iron.

22. Definition of steel.—Reasoning from the foregoing, steel is a *fusible, malleable alloy of iron produced in any way whatever, and containing a smaller proportion of carbon or other hardening element than is contained in cast iron, and is capable of receiving temper.*

23. Processes for obtaining cast steel.—There are a variety of processes for removing a portion of the carbon from cast iron and producing steel, among which may be mentioned: (1) melting in crucibles, giving *crucible steel;* (2) the open-hearth process, giving Siemens or *Siemens-Martin steel;* (3) the process of blowing air through molten cast iron, producing *Bessemer steel.* In whatever way made, the material is essentially the same, depending upon its chemical composition and physical structure for its properties. The open-hearth process is described later on.

24. High and low steel.—In consequence of the extension

given to the word *steel,* we have to-day under this name metals which present differences both as regards composition and physical properties. Hence, the different varieties of steel have been distinguished by the proportion of carbon—sometimes by numbers, and sometimes by more or less characteristic names. When the metal contains a large proportion of carbon, it is ordinarily called *high* or *hard steel* If the proportion of carbon is small, it is called *low* or *soft steel;* if still smaller, *extra low steel.* In some manufactories, for example, the name of low steel is given to a metal containing 0.20 to 0.25 per-cent of carbon, and a metal in which the proportion of carbon is less than 0.20 per-cent is designated *extra low steel.*

25. Nickel steel.—The use of nickel in steel for gun forgings has been found to impart some desirable qualities; and this alloy, containing definite proportions of nickel, can be successfully and uniformly produced by the open-hearth process; the use of nickel permits a reduction of carbon. The physical qualities of nickel steel vary greatly, according to the amount of nickel contained. A steel containing about 3¼ per-cent of nickel has, up to the present time, been generally used for gun forgings; and much information as to its qualities has been obtained. In general, the presence of this amount of nickel (3¼ per-cent) increases the tensile strength and elastic limit without causing a corresponding reduction in elongation and contraction of area; and the elastic limit is also increased relatively to the tensile strength. This condition indicates toughness. Crystallization after forging is also avoided; and a fine granular or amorphous condition results. This steel is more sensitive to temper, and it is in tempered steel that the improved qualities are most apparent. As shown by the ballistic tests of armor plate, the presence of nickel materially increases the resistance in shock. In short, the nickel improves the physical qualities of mild steel in all respects. It is thought probable that tubes of nickel steel may offer an increased resistance to the erosion of the bore of the gun as compared with simple steel, which is in the direction of obtaining greater hardness even at the expense of reducing the elongation.

Gun Forgings.

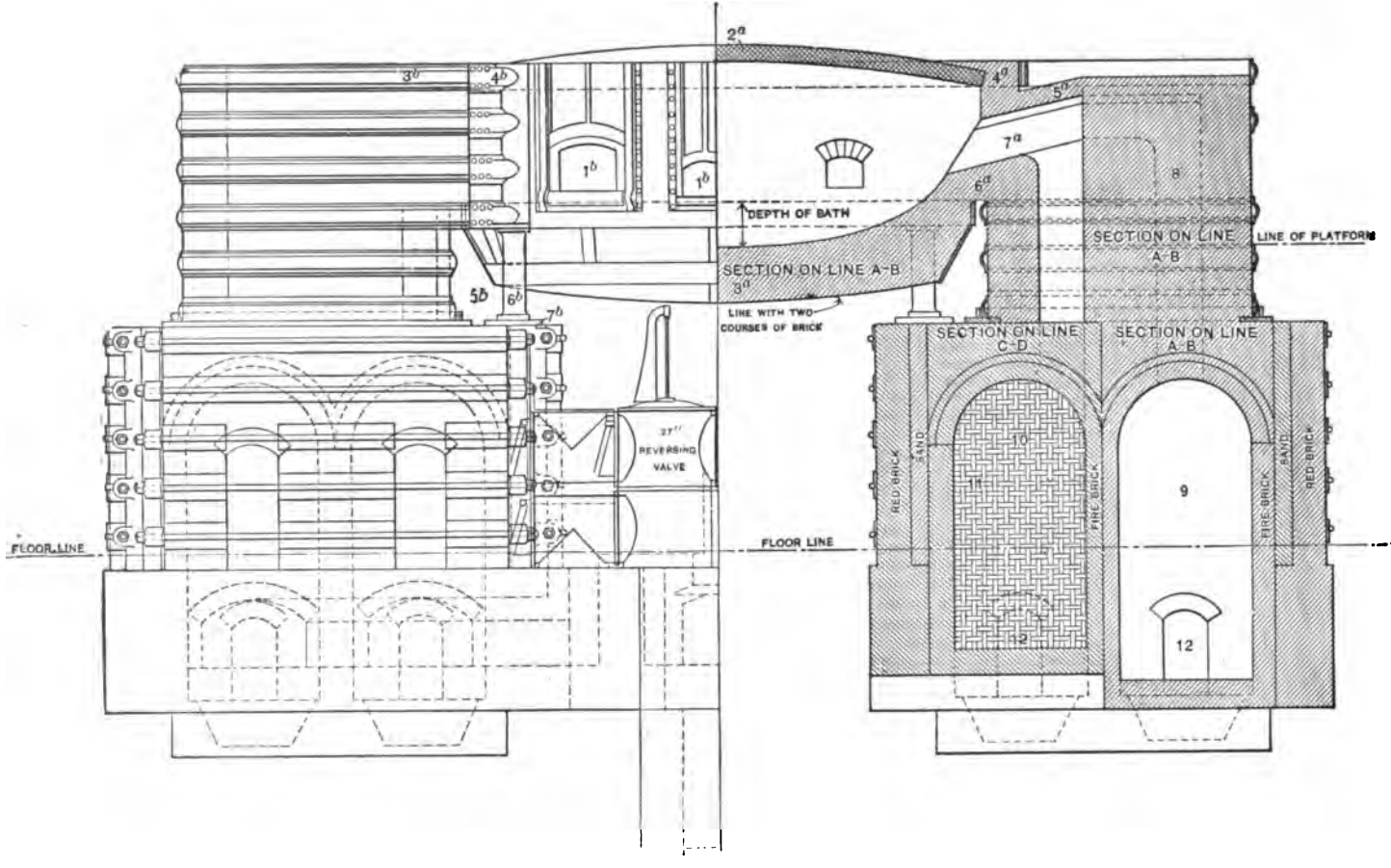
26. The open-hearth process.—As all gun forgings are made of open-hearth steel, only that process will be considered.

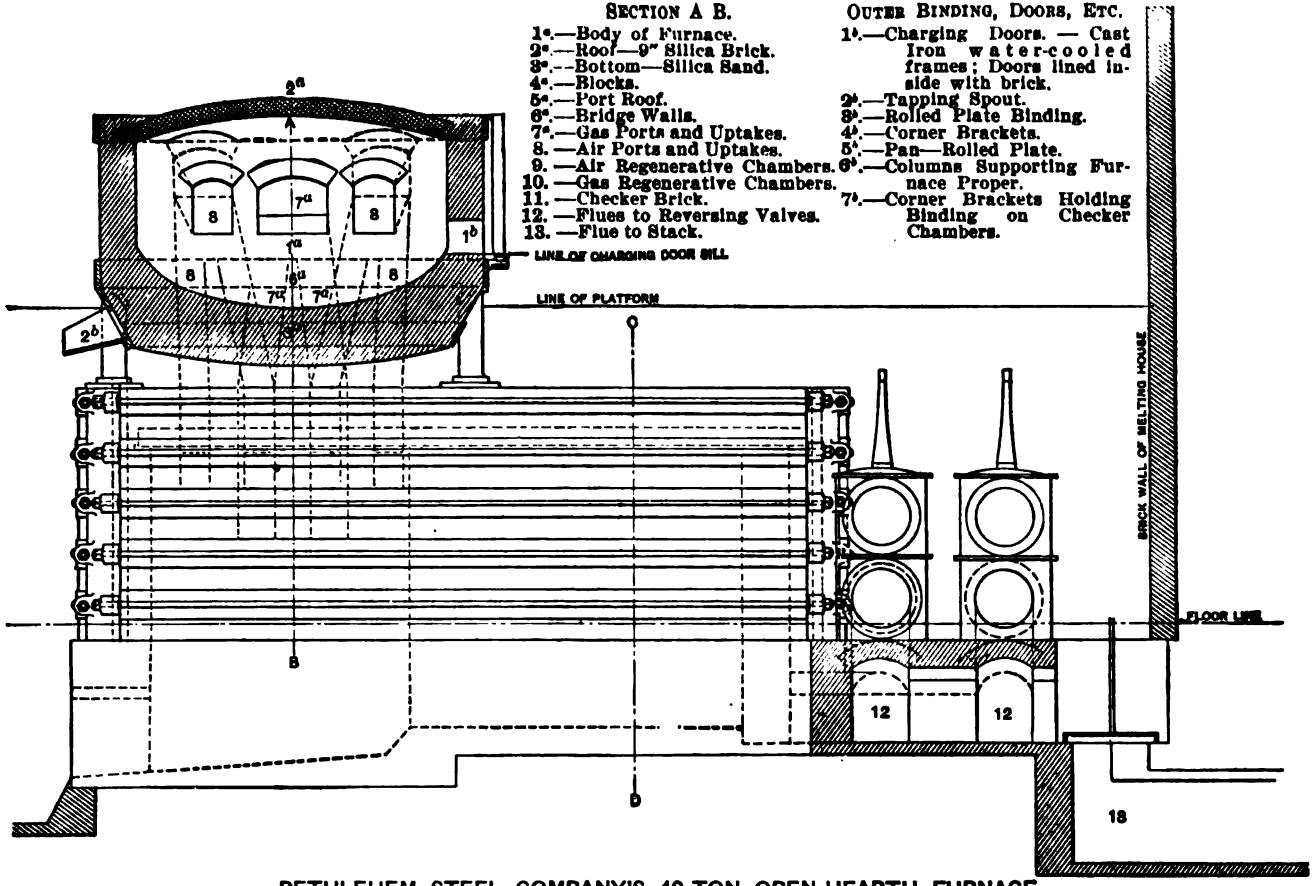
27. Iron is obtained from its ores by melting them in large blast furnaces with coke or coal, various fluxes being added, according to the nature of the ores, to carry off the earthy matters. The metal so obtained is run into sand or metal moulds in the shape of the well-known bars called "pig iron." The metal in this state is termed "cast iron," and contains various foreign elements, carbon and silicon principally. Cast iron contains by weight from 2 per-cent to 5 per-cent of carbon, which exists in two states, either chemically combined with the iron or mechanically mixed with it. If we remove the carbon from the cast iron so that the amount is less than 2 per-cent, we have either wrought iron or steel, according to the amount of carbon removed, or according to the subsequent treatment of the metal, or both combined. Theoretically, wrought iron approaches to pure iron, and contains from .1 to .3 per-cent of carbon. Extra soft or *low steels*, however, contain no greater proportion of carbon than this. Melted cast iron is reduced to wrought iron by puddling, or boiling, by the mere oxidation, or burning out, of the excess of carbon and silicon from the cast iron.

28. "* **The regenerative gas furnace** was invented by William Siemens, afterwards Sir William. A Frenchman named Martin used this furnace, developing what was known for some years as Siemens-Martin steel, or open-hearth steel; but now known only as open-hearth steel.

29. "At first, open-hearth steel was made upon a specially prepared sand bottom, by first melting a bath of cast iron and then adding wrought iron to the bath until, by the additions of wrought iron and the action of the flame, the carbon and silicon of the cast iron were reduced until the whole became a mass of molten steel. Sometimes iron ore is used instead of wrought iron as the reducing agent; this is called the pig and ore process. Now in general practice, wrought iron, steel scrap, and iron ore are used, some-

* Steel, William Metcalf.


2a
3b
4b
4a
5a
7a
6a
8
1b
1b
DEPTH OF BATH
SECTION ON LINE A-B
3a
LINE WITH TWO COURSES OF BRICK
SECTION ON LINE A-B
LINE OF PLATFORM
5b
6b
7b
SECTION ON LINE C-D
SECTION ON LINE A-B
27" REVERSING VALVE
RED BRICK
SAND
FIRE BRICK
10
11
9
FIRE BRICK
SAND
RED BRICK
FLOOR LINE
FLOOR LINE
12
12



BETHLEHEM STEEL COMPANY'S 40-TON OPEN-HEARTH FURNACE.

times alone and sometimes together, as economy and special requirements may determine. This is known as the open-hearth process.

30. "The fact that the phosphorus of the iron remained in the steel notwithstanding the active combustion and high temperature, led to the dictum that at high temperatures phosphorus could not be eliminated from iron. This conclusion was credited because, in some of the so-called direct processes of making iron when the temperature was never high enough to melt steel, all, or nearly all, of the phosphorus was removed from the iron. For many years steel makers the world over worked upon this basis, and devoted themselves to procuring for their work iron containing not more than ten points (.10 per-cent) phosphorus. Two young English chemists, Sidney Gilchrist Thomas and Percy C. Gilchrist, concluded that the question was one of chemistry, and not one of temperature, and set to work to obtain a basic lining, and to produce a basic slag which should retain in it the phosphorus of the iron. They succeeded, and produced a steel practically free from phosphorus. For the practical working of their process, it was found better, or necessary, to use iron low in silicon and high in phosphorus, using the phosphorus as a fuel to produce the high temperature necessary, instead of the silicon of the acid process. In the acid process, it is found necessary to have high silicon—2 per cent or more—to produce the temperature necessary to keep steel liquid; in the Thomas-Gilchrist process phosphorus takes the place of silicon for this purpose. This discovery, first applied in working out the basic Bessemer process, was tried in the open-hearth; a basic bottom of dolomite, or of magnesite, was substituted for the acid sand bottom, and care was taken to secure a basic slag in the bath. Success was greater than in the Bessemer process; phosphorus was eliminated and a product better in every way obtained. This, the basic open-hearth process, is now used extensively over the whole civilized world.

31. "Neither the basic nor the acid process removes sulphur, so that this element must still be kept low in the original charge, until some way be found for its sure and economical elimination. If too much sulphur be present, the steel cannot be worked conveniently under the hammer."

32. "* **The Siemens regenerative gas furnace** consists of three parts, viz., (1) the producers or apparatus for the generation of the crude gas; (2) the regenerators or chambers filled with a checker work of fire-bricks, which alternately absorb and store up the waste heat of the flame and gases as they escape from the furnace hearth, and then subsequently give up this heat to the gases from the producers, and to the air for supporting their combustion, as each of them passes through the separate regenerators before meeting for combustion upon the bed or hearth of the furnace; and (3) the furnace structure proper."

33. Plate I shows the details of a 40-ton open-hearth furnace of the Bethlehem Steel Works.

34. On an elevated platform are located a number of these furnaces to which the charge of raw material must be raised. During the process of melting, a small dipperful of the molten metal is, from time to time, taken out of the furnace and rapidly tested, to find out how the refining is taking place; and when the charge is ready, the metal is poured from the furnace into ladles, which in turn empty into moulds located in the casting pit underneath. Plate II shows a ladle and an end view of the pit.

35. Carbon.—In the acid open-hearth process, it is usual to burn the carbon out almost entirely, and then add the desired amount with the spiegel-eisen or ferro-manganese. Higher carbon may be obtained by the addition of pure pig iron. In good practice, the melt is stopped at the carbon desired with great success, thus saving time and expense. In the basic open-hearth the melter, by care and good judgment, stops his melt at the required carbon, and so avoids any additional operations, unless his charge is excessively high in phosphorus, and his steel is to be very low in the same; in that case, he may have to melt clear down and recarbonize. Steel of 1.30 per-cent carbon with phosphorus less than .05 per-cent may be made on the basic hearth from a charge containing .10 per-cent to .12 per-cent phosphorus without melting below 1.30 per-cent carbon.

* Steel and Iron, Greenwood.

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OPEN

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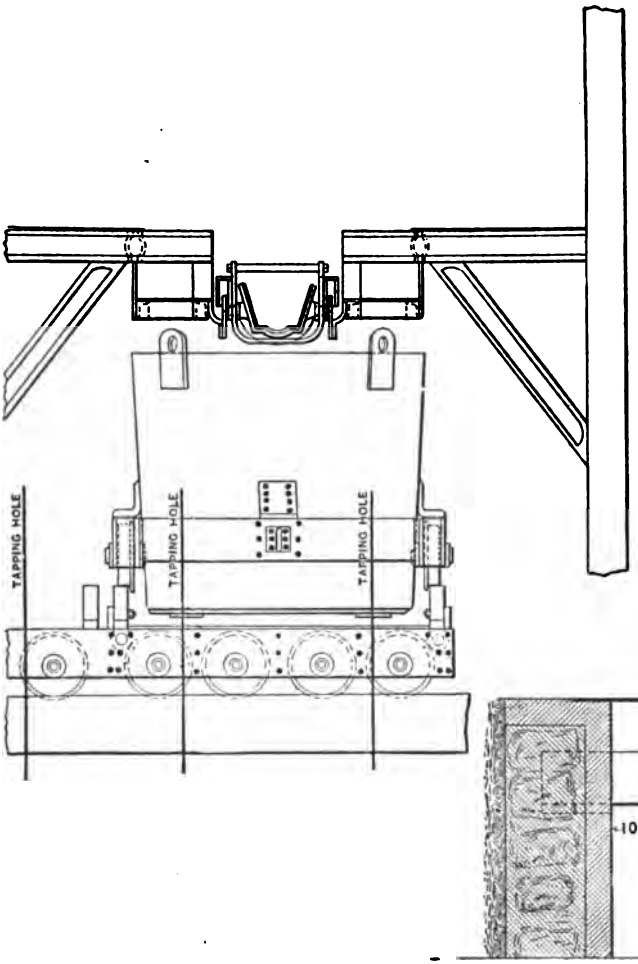
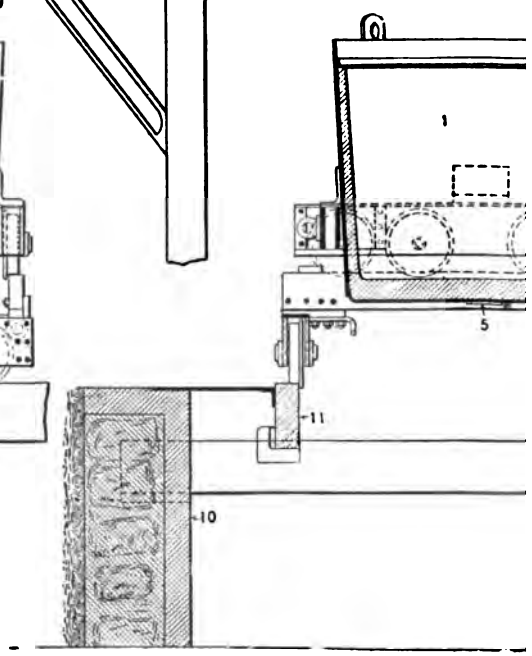
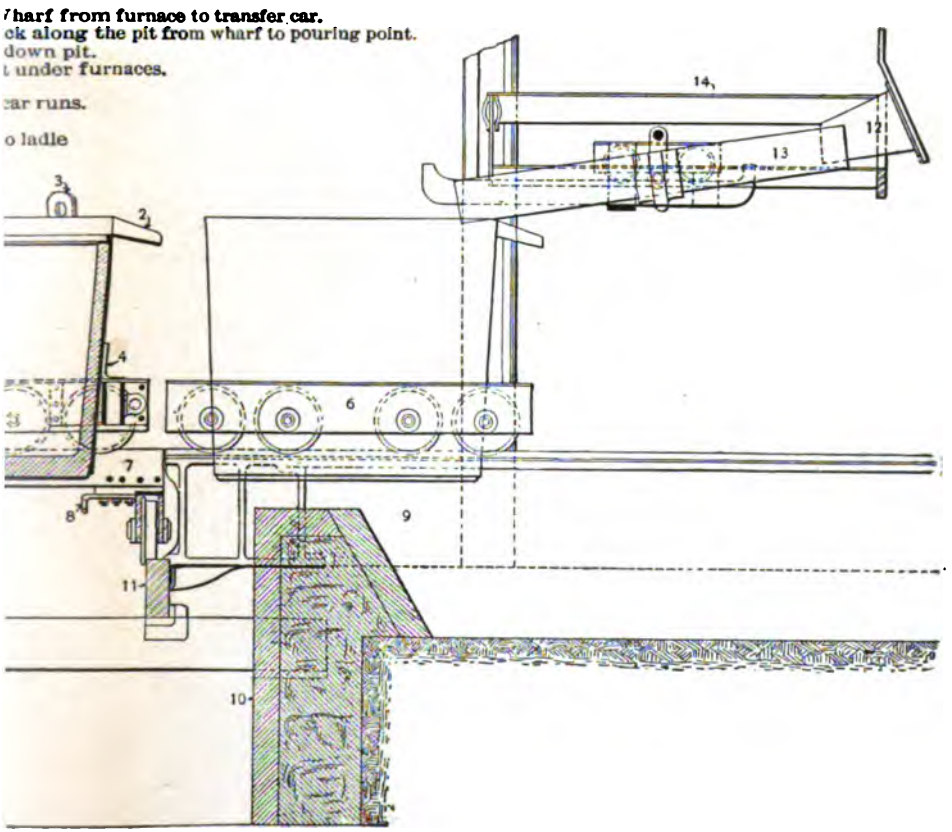


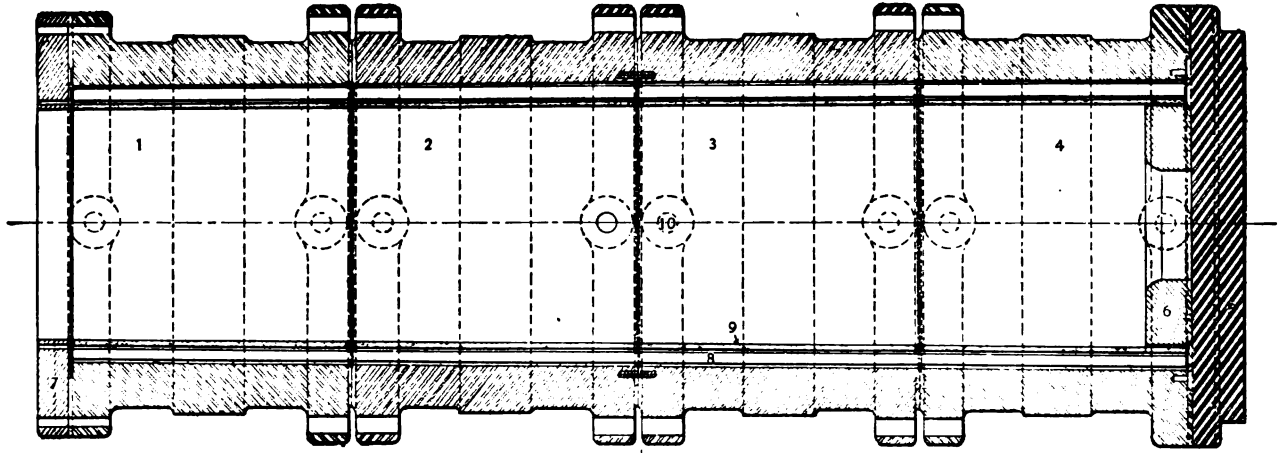
1 Ladle—Shell of ¾" rolled plate
2 Spout.
3 Lugs—For handling.
4 Brackets—to rest on truck.
5 Nozzle holes.
6 Ladle Truck—runs on Ladle
7 Transfer Car—Carries ladle tr
8 Lugs—for drawing car up and
9 Ladle Wharf—extends from p
10 Walls of pit.
11 Rails of pit on which transfer
12 Spout of furnace.
13 Trough—from furnace spout
14 Charging platform.



EHEM STEEL CO
HEARTH PLANT.
STING PIT.

Lined with fire brick.

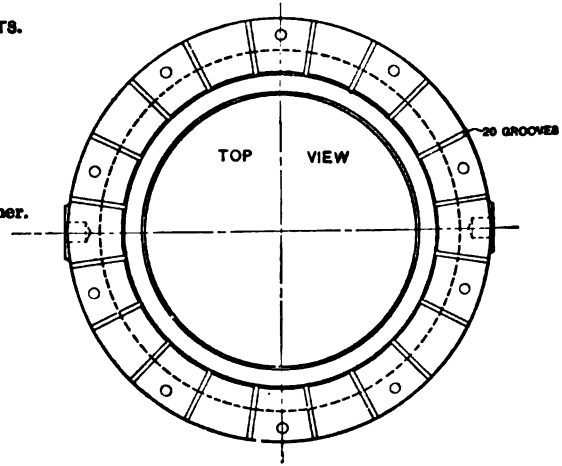




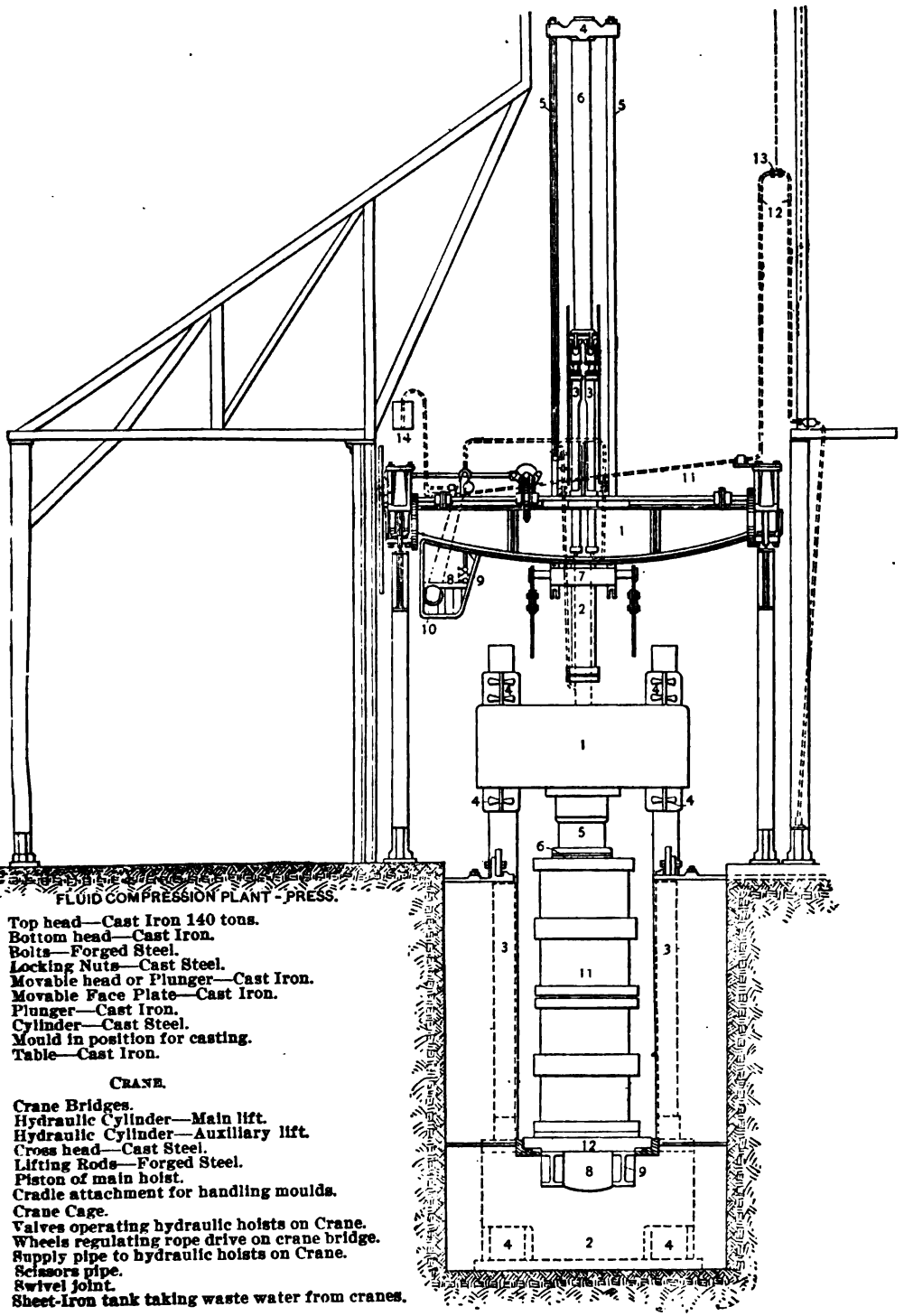
42"RD. MOULD FOR POURING FLUID COMPRESSED INGOTS.

1 2 3 & 4	Sections of mould.	Cast Steel.
5	Bottom	Cast Iron
6	Well Plate	" "
7	Top Ring	" "
8	Staves	" "
9	Lining	Sand
10	Holes for pins for Handling.	

Bottom is clamped on. Sections are bolted together.
Grooves in joints for gas vents.



THE BETHLEHEM STEEL CO.
42-Inch Ingot Mould.
FLUID-COMPRESSION PLANT.



FLUID COMPRESSION PLANT - PRESS.

1 Top head—Cast Iron 140 tons.
2 Bottom head—Cast Iron.
3 Bolts—Forged Steel.
4 Locking Nuts—Cast Steel.
5 Movable head or Plunger—Cast Iron.
6 Movable Face Plate—Cast Iron.
8 Plunger—Cast Iron.
9 Cylinder—Cast Steel.
11 Mould in position for casting.
12 Table—Cast Iron.

CRANE.

1 Crane Bridges.
2 Hydraulic Cylinder—Main lift.
3 Hydraulic Cylinder—Auxiliary lift.
4 Cross head—Cast Steel.
5 Lifting Rods—Forged Steel.
6 Piston of main hoist.
7 Cradle attachment for handling moulds.
8 Crane Cage.
9 Valves operating hydraulic hoists on Crane.
10 Wheels regulating rope drive on crane bridge.
11 Supply pipe to hydraulic hoists on Crane.
12 Scissors pipe.
13 Swivel joint.
14 Sheet-Iron tank taking waste water from cranes.

THE BETHLEHEM STEEL CO.

GENERAL ARRANGEMENT OF CASTING PRESS AND CRANES.

The Casting of the Ingot.

36. Steel ingots for guns are cast solid by the Whitworth process, and are known as fluid-compressed steel. The object of compressing the liquid metal in the mould immediately after casting is to get rid of the blow holes, and to obtain a metal of high density. Blow holes are cavities caused by air imprisoned when pouring the metal into the mould; at certain stages in cooling, gas is generated, also causing blow holes.

37. The mould or flask.—The flask into which the molten metal is poured from the ladle is made of steel, and is built up of sections united by broad flanges bolted together in such numbers as to accommodate the length of the ingot to be cast. The interior of the flask is lined with long rods square in section, longitudinally arranged, which form when in place a complete cylindrical interior surface. Where the square edges of these rods meet they are cut away, both on the inside and on the outside, and, at intervals of two inches small holes are drilled through between the rods, forming a channel-way from the interior to the exterior for the passage of gas and flame. The interior is then lined with moulding composition. The flange at the bottom of the flask, as well as that at the top, is perforated with small holes which act as continuations to the perforations between the segments of the lining for the escape of gas. The details of the mould for pouring fluid compressed ingots are shown in Plate III.

38. Fluid-compression.—The metal is poured directly into the mould from the top. The mould is then moved (by means of a railway at the bottom of a casting pit, which is a deep trench running parallel to the position of the furnaces) to a position under the movable head of the press which is allowed to descend until the piston is in contact with the metal in the mould, and in this position it is locked; a shower of metal is caused, which ceases almost immediately by the complete closing of the mould. The first impress felt by the metal is due to the weight of the press alone; this pressure is gradually increased from below by hydraulic action, applied by four rams upon the table on which the flask rests, until the pressure exerted amounts to 6 tons per square inch. During the period of compression, the flow of gas and flame

from the apertures in the flanges of the flask, at top and at bottom, is continuous and violent, exhibiting the practical effect of the compression. This pressure is applied by the direct action of steam and pumping engines, and is indicated by a dial. After the maximum pressure is reached, the pump is taken off, and a uniform pressure of about 1500 pounds per square inch is established by attaching an accumulator to the press, and allowed to remain until the metal is sufficiently cool to insure no farther contraction in the mould.

39. The contraction in length in the mould during the action of the pump, while the maximum pressure is being reached and sustained, amounts to one-eighth the length of the ingot. After this effect has been produced, there is no farther advantage derived from the pressure in the way of eliminating impurities, but the contraction in cooling still goes on, and the pressure by the accumulator is considered necessary, in order to follow up the metal as it contracts, to prevent cracks being started at the end and on the exterior of the ingot by the adhesion of particles of the metal to the sides of the mould. The details of the fluid press, mould, and cranes are shown in Plate IV.

40. Defects of ingots.—Beside blow holes, ingots often show "piping" and "segregation." The metal, when it is poured into a mould, cools and solidifies first at the surface of the mould; and, as the solid metal keeps cooling toward the center, it shrinks and draws away from it. This shrinkage draws principally from the center and top, these being the parts that solidify last. It is, therefore, to take care of this shrinkage that more metal is added to the length of the ingot than would otherwise be required. The hydraulic pressure applied at the top forces the fluid metal from this added part down through the center, and keeps the latter filled where otherwise there would be a cavity or "pipe." Segregation occurs principally in large ingots. This is a separation of the various ingredients of steel (sulphur, phosphorus, manganese, silicon, etc.), each of which has its own temperature of cooling. As the mass cools, the tendency of these ingredients is toward the central and upper portions, where they cool, thus forming a central core of impurities. Even the fluid-compression does not entirely prevent this. A solid ingot is, however, obtained, which is abso-

lutely necessary, as steel will not readily weld; so that original defects in the ingot cannot be later remedied by hammering.

Processes after Casting.

41. The discard.—The extra length, having served its purpose of supplying metal to fill "blow holes" and "pipes," and of collecting segregation, is cut off and returned to scrap.

42. With fluid-compressed ingots, the required discard is 10 per-cent of the weight of the ingot from the upper end, and three linear inches from the lower end.

43. Coring.—In good practice, the ingot is cored before the next process, that of forging, particularly if it be a large ingot. The discard having been cut, the ingot is centered in a heavy lathe and an axial hole bored, which varies in size according to the diameter of the ingot. Small ingots may be forged without coring, but it is not usual for gun forgings.

44. Forging.—The *reheating* of the ingots before forging is a delicate operation, as great care must be taken to make the heat penetrate the metal slowly and uniformly. As already explained, the metal in the ingot, during the process of cooling, is being drawn out in all directions to fill the mould. When it is cold, therefore, it is in a condition of strain throughout its interior. If it were put cold into a hot furnace to be reheated, the surface metal would immediately expand, and draw farther away from the center, causing an additional strain on the inside metal. In very large ingots, cracks are thus apt to form in the center, and the forgings are liable to break later in service, from the fact that they have not been properly reheated.

45. Forging solid.—Metal may be forged by hammering or by pressing; a great deal of work is put into it in either manner. If pressed, the pressure applied should be such as to penetrate the ingot to its center, causing a flow of metal throughout the mass. This flow of metal requires a certain amount of time, during which the pressure must be maintained. For this reason, the forging presses, now in general use, seem preferable to hammers, as, under their slow motion, time is allowed for the molecules of the metal to move easily upon each other, the pressure is felt

throughout the mass, and the final adjustment and distribution of molecules is better.

46. Forging hollow.—In the manufacture of hollow forgings, the conditions of shaping are in all respects favorable to the production of sound work of the highest quality. A forging mandrel is merely a cylindrical steel shaft (sometimes hollow and sometimes solid), with a long tail piece or handle which may be a part of the mandrel or be screwed into it. The bored ingot is forged upon the body of the mandrel, thereby decreasing its external diameter as well as its thickness of wall; the length is necessarily somewhat increased. The mandrel occasionally gets hot and sticks, necessitating its removal by hydraulic power, or even by cutting, but a skilled man rarely permits this to happen. The axial hole, into which the mandrel fits, removes the portions most likely to have been made defective by segregation and piping; any interior defects which may not have been removed by boring are rendered visible as well. The bored ingot forms a hollow cylinder with walls much thinner than the cross-section of the solid ingot; this greatly facilitates heating and practically eliminates the danger of internal cracking during the reheating. The forging of the comparatively thin walls of the cylinder over a solid mandrel makes it possible to turn the forging out at a low and uniform heat, thus fixing a uniformly fine or amorphous grain. A solid forging, on the other hand, of the same outside diameter, would be much hotter toward the central axis than on the outside; and the gradual loss of this high internal heat will tend to coarse the grain by crystallization, and set up interior strains. In the hollow forgings, any internal defects are visible, while their presence in solid forgings are hidden and can only be disclosed by boring.

47. Reduction by forging. (Navy specifications.)—(1) *For tubes, plugs, and mushrooms,* each ingot will be reduced in diameter, by forging, at least 50 per-cent at the largest diameter of the piece, and at no point less than this. For jackets, each ingot will be reduced in diameter, by forging, at least 40 per-cent at the largest diameter of the jacket, and at no point less than this.

(2) *In case tubes are forged on a mandrel* from bored ingots, the walls of the ingots at all points must be reduced in thickness

by forging, at least 50 per-cent. In case jackets and hoops are forged in the same way, the walls of the ingots at all points must be reduced in thickness, by forging, at least 40 per-cent.

(3) *In case hoops are forged from solid ingots* by upsetting and punching and subsequent elongation or enlarging on a mandrel, the walls at all points must be reduced in thickness, by forging on the mandrel, at least 33 per-cent.

48. Annealing.—The next process is that of annealing. The primary object of annealing is to relieve the internal strains set up by forging, and by the rapid and irregular cooling during and after forging. Further, annealing alters the molecular condition of the steel, and when applied under proper conditions, has a tendency to break up crystallization and fix a finer or more nearly amorphous grain, whereby the toughness of the material is increased.

49. The process of annealing.—To anneal steel, the ingot is heated to a red heat, and then left to cool slowly. The particles thus readjust themselves to a normal condition. This may be done in a furnace by drawing the fires after heating, or by packing the ingot with cast iron borings or ashes so that it is protected from the air; the process sometimes takes several days for a large ingot. The general effect of annealing, as indicated by the tensile tests of *tempered specimens,* is to lower the tensile strength and elastic limit and to increase the elongation and contraction of area.

50. Tempering, or hardening; of steel forgings consists in cooling them rapidly, usually by immersion in oil, from a red heat varying in degree according to conditions, and hence it is generally spoken of as *oil tempering.* The object of this treatment is, first, to break up the irregular and more or less laminated and coarse crystalline structure produced by forging, and to fix a fine or amorphous condition of grain; and second, to modify the physical properties of the metal, in order to obtain the most desirable combination practicable.

51. *The sudden cooling in oil,* or otherwise, naturally produces strains which, unless properly guarded against and relieved, are hurtful, and, under certain conditions, may be so great as to cause actual rupture. To avoid this latter danger, precautions as

to shape as well as to composition and heating are necessary, but of first importance is the removal of the metal along axial lines before tempering, so as to effect internal as well as external cooling. This must often be done by machining, but it is evident that forging hollow furnishes a product especially adapted to tempering.

52. The process of tempering.—A tube of steel is lifted by a powerful crane and placed in a perpendicular position in an upright furnace which has been previously heated with wood or gas fuel to a red heat. It rests on an iron shoe placed on the grate bars to prevent the cold air from coming in contact with its extreme end. Great care is taken to heat the mass uniformly.

53. *The amount of heat received by the steel* is judged by eye—the color of the heat being the guide—and by long practice and attention. The more uniform the temperature, the straighter the tube will keep, and the more even its temper. After the steel has acquired the proper uniform temperature throughout, the traveling crane is brought over the furnace, its top removed, and the large iron tongs, pendent from the crane, fasten themselves to the steel tube, a small collar being upon its end to prevent the tongs slipping.

54. The oil bath.—(1) The tube of steel is now drawn out of the furnace and sunk into a large iron tank of suitable depth containing several thousand gallons of oil. The heated steel, in passing into the oil, will sometimes cause the surface oil to take fire, which is extinguished by closing the top of the tank.

(2) A covering of coal is also formed round the steel by the burned oil, which greatly retards transmission of heat.

(3) The tank has a water space surrounding it, and as the steel parts with its heat, raising the temperature of the oil, the temperature of the water is also raised. The water, as it is heated, is drawn off by an escape pipe, and a supply of cold water is continually running in, so that the heat is gradually taken from the mass. Exceeding toughness is the result of the operation; the tensile strength of the steel is made higher, and it is harder and more elastic.

55. Re-annealing.—*Annealing is again resorted to after tempering;* first, to relieve strains, and secondly, to soften the metal

to a degree required to obtain the physical qualities aimed at. The effect of this double treatment—tempering and annealing—as indicated by tensile tests, is, in general, to increase the elastic limit relatively to the tensile strength, and, when the hardness is "drawn" by annealing, to increase materially the elongation and especially the contraction of area.

56. Recapitulation of processes.—The various processes through which the steel passes may be stated in their order as follows: (1) *casting*, (2) *forging*, (3) *annealing* to get rid of strains induced by forging, (4) *tempering*, and (5) *re-annealing*. The last process, by whatever method followed, must be an annealing one. Before acceptance and delivery, specimens are cut from the forging and tested to determine if it meets the requirements of the specifications.

57. The effect of tempering and annealing.—The effects of temper on the physical properties vary with the nature of the steel, and are much more pronounced as the steel is more carbonized and homogeneous.

58. The following table, from tests made by the Navy Department, will give an idea of the effect of oil temper on the physical properties of mild or medium hard steel:

ELASTIC LIMIT OF STRESS.		TENSILE STRENGTH.		ELONGATION.	
Before tempering. Tons.	After tempering. Tons.	Before tempering. Tons.	After tempering. Tons.	Before tempering. Inches.	After tempering. Inches.
13	29.2	26.8	45.2	.737	.433
13	27.8	27.8	46.0	.707	.345
12	26.0	27.6	39.6	.713	.420
12	25.8	28.0	41.0	.633	.480
13.77	34.15	28.11	49.8	.596	.260
12.18	34.8	26.9	49.4	.564	.202

59. Thus it will be seen that the elastic limit of stress is more than doubled, the tensile strength raised more than 60 per-cent, while the elongation is reduced over 40 per-cent.

60. The re-annealing process reduces the tensile and elastic strength from 10 to 15 per-cent, and restores the ductility, as measured by the elongation, from 25 to 40 per-cent.

61. Determination of the physical properties.—This is accomplished by subjecting specimens of the metal to the action of different stresses in testing machines, and observing the effect on the specimens in alteration of volume and figure by means of accurate measuring instruments.

Testing Machines.

62. The testing machines are generally a combination of levers for recording the stress, and a system of gearing or hydraulic machinery by which the stress is produced.

63. Specimens are usually prepared to an adopted shape. In the case of gun metals they are cylindrical, and are turned to the same diameter for a certain length, usually not less than two inches and not more than ten inches for tensile tests; and in addition, ends are allowed for the purpose of attaching the specimen to the machine. For compressive tests the specimen is also cylindrical, the height being twice the diameter. The capacity of the machine limits the diameter of these specimens.

64. In making a tensile test, the specimen is marked at two points as far apart as the finished length between grips will allow, and the length is carefully measured between these points. The diameter is also measured by micrometer calipers. It is then placed in the machine and subjected to successive tensile stresses, the elongation being noted for each stress, both when the load is on and after it has been removed.

65. Elastic limit.—When a permanent set, equal to the smallest division the measuring instrument is capable of recording, is shown, the elastic limit of strain has just been reached within the limits of accuracy of the instruments, and *the corresponding stress is the elastic strength* of the metal. It is usual to increase the load by small increments when near the elastic limit. If the elongation is not noted, the elastic limit may be determined approximately by watching the weighing lever as the increments of the load are put on; if the lever remains steady, the limit has not been reached; but when a load is put on and the lever falls after it has recorded the stress, it shows that the metal has permanently stretched. The corresponding strength is then the elastic strength, approximately. The elastic elongation should, however, be recorded whenever possible.

66. Tensile strength.—After the determination of the elastic strength, the specimen is subjected to further stress until rupture takes place. The highest record made by the weighing bar is the *tensile strength.* After rupture, the pieces are joined, and the distance between points measured; the percentage of total elongation is thus determined. Similarly, the percentage of reduction of area is found by measuring the diameter at the point of fracture.

67. To obtain the elastic limit of stress for compression, a compressive stress is put on the specimen, and the height of the cylinder carefully measured; the stress which produces the smallest permanent set observable is the elastic strength for compression, within the limits of the accuracy of the instruments.

68. Tensile and elastic strengths are expressed in pounds or tons per square inch; elongation, as elongation per inch, or per-cent of elongation per total length. The results are reduced to standard for area and length.

69. Comparative strength of forgings.—It will be seen from an inspection of the tables given below, showing the requirements of the Navy Department regarding the elastic and tensile strengths of tubes, jackets, and hoops, that the hoops are stronger than the jackets, and the jackets stronger than the tubes. Manifestly, it would be desirable that the opposite rule should obtain—that the tube should be the strongest part of the structure. The explanation is to be found in the fact that it is impossible to make a *large* mass of steel as nearly perfect as a *small* piece. The smaller the forging the more uniform its texture and the more readily and the more perfectly will it yield to the processes of annealing, tempering, etc.,—the processes that affect its tensile and elastic strength. The Navy Department is forced to recognize these facts in its specifications. This matter will be referred to later on in discussing the principles of gun construction.

FOR GUNS OF 8-INCH CALIBER AND BELOW.

	Tubes.	Jackets.	Hoops.	* Plugs.	* Mushrooms.
Tensile strength ..... in lbs.	85,000	90,000	95,000	90,000	90,000
Elastic limit of stress..... "	45,000	50,000	55,000	60,000	60,000
Elongation after fracture	†18	†18	†18	†18	†18
Contraction of area.....	†30	†30	†30	†30	†30

* Nickel steel. † Per-cent.

FOR GUNS ABOVE 8-INCH CALIBER.

	Tubes.	Jackets.	Hoops.	* Plugs.	* Mush-rooms.
Tensile strength ..... in lbs.	85,000	88,000	95,000	90,000	90 000
Elastic limit of stress..... "	45,000	50,000	55,000	55,000	55,000
Elongation after fracture	†18	†18	†18	†17	†17
Contraction of area	†30	†30	†30	†30	†30

* Nickel steel. † Per-cent.

70. When forgings are required to be of nickel steel the physical requirements for guns of all calibers shall be, with about 3½ per-cent of nickel in all forgings, as follows:

	Tubes.	Jackets.	Hoops.	Plugs.	Mush-rooms.
Tensile strength .... in lbs.	90,000	90,000	95,000	As prescribed for the different calibers in the above tables.	
Elastic limit of stress..... "	55,000	60,000	65,000		
Elongation after fracture	*18	*18	*18		
Contraction of area	*30	*30	*30		

* Per-cent.

71. Government tests and inspection of gun forgings. (Specifications of Bureau of Ordnance.)

(1) *To ensure compliance with all specifications,* the Bureau shall have the right to keep agents or inspectors at the works where the guns and mounts are built, who shall have free access to all parts thereof, and who shall be permitted to witness all the processes of manufacture, and to examine all the contractor's records with reference to such matters.

(2) *Forgings are to be made of open-hearth steel,* of domestic manufacture, from the best quality of raw material, uniform in quality throughout the mass of each forging and throughout the whole order for forgings of the same caliber, and free from slag, seams, cracks, cavities, flaws, blow holes, unsoundness, foreign substances, and all other defects affecting their resistance and value.

(3) *Forgings are to be annealed,* oil tempered under such conditions as will assure their resistance, and again annealed. No piece will be accepted, nor will its test specimens be broken or considered, unless the last process has been an annealing one. The forging must be left with a uniform fine grain.

(4) All pieces forged solid must be annealed and otherwise treated after being rough-bored and turned to the above dimensions. Pieces forged on a mandrel may be annealed before being rough-bored and turned. Hoops whose forged thickness is less than 4 inches may be treated and tested before being rough-bored and turned.

(5) The contractor must deliver each forging and casting in such condition as to allow of its being finished true and to the dimensions that were standard at the time said piece was rough-bored and turned, ordinary care being exercised in machine work.

(6) If the inspector finds that any part of a forging has received less hammering or other beneficial treatment than it should properly have received, as compared with the parts from which test bars are to be taken, the piece will be rejected.

(7) After the final forging, all heating must be uniform or uniformly graded throughout the entire piece, and all heating for tempering and all immersing shall be executed with the forging in a vertical position. The whole of the piece must be subjected to the treatment at the same time.

(8) The contractor shall state for each piece, in writing, the exact treatment it has received.

(9) The inspector shall examine all fractures of the metal, in the course of manufacture, for the purpose of determining whether it is of uniform and homogeneous structure.

(10) Forgings presented for provisional tests and acceptance will be critically inspected for defects of soundness and workmanship (as aforementioned). The records and facts as to their composition and treatment, and all other matters affecting them, will be considered, and they will be subjected to physical tests. They must conform to the requirements in all particulars, and must meet all inquiry and tests successfully in order to be provisionally accepted.

(11) *Physical tests* will be directed toward the exhibition of all the principal physical qualities of the metal. Those to which particular attention will be devoted are tensile strength, elasticity, and extensibility.

(12) These tests are to be made on cylindrical specimens 2 inches long between measuring points and ½ inch in diameter. The specimens are to be taken from the forgings after final treatment *transversely to the axis of the bore of the finished gun,* and within the finished section prolonged. They are to be taken as near the finished piece as practicable, leaving sufficient metal for submitting additional test bars in case of re-treatment.

(13) Test specimens shall not be cut off until from examination the forging is known to be sufficiently straight to machine-finish to the required dimensions. If any doubt as to this exists the forging must be heated and straightened and then re-annealed before testing.

(14) Test bars shall be cut and tests made under the supervision of an agent or inspector of the Department, who may make the tests personally if he should so desire. He will stamp and have the custody of each test bar.

(15) If the contractor provides a testing machine of a pattern approved by the Department, the tests may be made at his works; otherwise the test bars will be suitably packed and delivered by the contractor, for transportation to such place as the Department may direct. The expense of

testing in this latter case will be borne by the Department. The contractor has the right to be present at tests outside his works. Under any circumstances the Department may, if it so elects, have the tests made at any place.

(16) The contractor shall first present three specimens from each end of a tube or jacket, from the end nearest the upper end of the ingot or casting of each hoop or plug, and from mushrooms, two transverse specimens from the head and one longitudinal specimen from the stem. The central axis of these longitudinal specimens from the mushroom stem need not be nearer the central axis of the forging than one-half of the radius of the latter.

(17) In case the length of any hoop-forging exceeds two and a half times its interior diameter, two specimens shall be presented from each end of such forging, instead of three specimens from the upper end.

(18) The specimens taken from either end of forgings shall be considered independently of those taken from the other end of the same piece.

(19) If all the specimens from any forging show physical qualities in each particular equal to or exceeding the figures in the table (see Art. 69), the forging shall be provisionally accepted, but if more than one specimen from either end of the forging fail to do so, the forging shall be rejected.

Steel for Armor.*

72. Face-hardened armor.—We have seen that gun forgings are made of homogeneous steel. Armor is also made of steel, but the face of the plates is hardened by a process of super-carbonization; the aim is to make this hard face more rigid than the point of the projectile and, at the same time, to have the plate as a whole too tough to be shattered by the impact. Two kinds of face-hardened armor are used in the U. S. Navy—the "Harvey" and the "Krupp."

73. The Harvey process is used for plates having a thickness of five inches or less; the Krupp process for those having a greater thickness than five inches.

74. Thin plates and hollow forgings, such as turret tops, doors, communication and ammunition tubes, are made of homogeneous nickel steel, oil or water-tempered and annealed, but not face-hardened. The bolts are of the best quality of nickel steel, oil or water-tempered and then annealed; they contain about 3¼ per-cent of nickel.

75. Harvey armor contains carbon, manganese, nickel, silicon, phosphorus, and sulphur. The amount of phosphorus, sulphur,

*Revised by Lieutenant Cleland Davis, U. S. Navy.

and silicon is kept as low as possible, while the carbon, nickel, and manganese are present in predetermined quantities.

76. Krupp armor contains carbon, manganese, silicon, phosphorus, sulphur, nickel, and chrome; the nickel, carbon, manganese, and chrome appearing in predetermined quantities, while the silicon, phosphorus, and sulphur are kept at a minimum.

77. The addition of nickel (about 3¼ per-cent), aided somewhat by the small percentage of manganese in the case of Krupp armor, gives great strength and toughness. The further addition of the chrome gives the metal more sensitiveness to temper, thereby permitting a greater depth of chill below the surface. It increases the affinity of the metal for carbon, which results in super-carbonization to a greater depth, and, with careful treatment, gives the plate a tough fibrous back which resists cracking. It is this quality which marks the superiority of Krupp armor.

78. Typical chemical composition of Harvey and Krupp armor:

	C.	*Mn.*	*Si.*	*P.*	*S.*	*Ni.*	*Cr.*
Harvey	.30	.80	.10	.04	.02	3.25	0.00
Krupp	.35	.30	.10	.04	.02	3.50	1.90

CHAPTER II.

NAVAL RIFLED-GUNS.

General Discussion.—Definitions.

1. Rifled-gun.—A *rifled*-gun is so called on account of the spiral grooves which are cut in the surface of the bore, and into which the projections or soft metal bands on the projectile are forced, thus imparting rotation to the projectile about its longitudinal axis when it is driven out of the bore. When the charge and projectile are placed in the gun from the breech end it is termed a *breech-loading gun,* and is generally designated by the caliber in inches, and by the initials B. L. R.; by R. F. if a *rapid-fire gun.*

2. Lands.—The spaces between grooves are called lands.

3. Rib-rifling.—When the grooves are very wide and the lands very narrow the gun is said to be *rib-rifled,* and the lands are called *ribs.*

4. Caliber.—The caliber of a rifled-gun is the diameter of a cylinder which touches the *highest* points of all the *lands.* In the case of rib-rifling it is the diameter of a cylinder which touches the *lowest* point of all the grooves.

5. The term "Mark."—(1) For the sake of convenience or brevity, each gun of whatsoever caliber that differs considerably from those preceding, is given a "mark," numbered serially, thus: 6-inch Mark I, 6-inch Mark VI, etc. There may be one, or a large number of guns in each mark.

(2) The differences creating marks may lie either in the construction of the gun, type of breech mechanism, manner of mounting (if a change on the gun is involved), or a difference in some important part or dimension.

(3) This system of marks is carried on throughout ordnance, not only for guns, but for gun-mounts, breech mechanisms, sights,

powder tanks, firing mechanisms; in fact, all articles made according to standard drawings.

NOTE.—Guns, mounts, sights, fuses, etc., are designated by "marks" and "modifications": "Mark II, Mod. I," indicates a slight modification of Mark II, not sufficient to necessitate a new mark.

"Mark II, Exp. I," indicates an *experimental design.* Should it be adopted in the service, the letters "Exp." may be crossed out, and it may be assigned a definite "mark" or "modification."

6. The bore of a gun is the cylindrical hole cut, or left, in the direction of the length and in the axis, to form a path for the projectile. It serves also to contain the powder charge before firing, as well as to confine the powder gases after firing. In all modern breech-loading guns, the bore extends from the rear face of the gun tube to the muzzle face. This is called the *length of the bore.*

7. Length in calibers.—It has become customary to designate guns by their length in calibers; for example, a "30-caliber 6-inch B. L. R." This term defines the *total length* of the gun, and gives an approximate idea as to its power. But a more accurate method of comparing the power of guns in the same caliber is to give the *travel of the projectile in the bore* in calibers, since the velocity, and therefore the power of the gun, is a function of the *travel.*

8. Powder chamber.—The powder chamber is that part of the bore in which the powder charge is placed, and the *capacity* of the powder chamber is the cubical contents of all the space between the base of the projectile and the face of the breech-plug, whatever the shape of that space may be. Powder chambers in high-powered B. L. guns are larger in diameter than the remainder of the bore. The cylindrical part of the chamber is joined to the "compression slope" by an easy slope called the "slope of the powder chamber." The "compression slope" is the short and comparatively steep slope against which the rotation band seats when the projectile is rammed home.

9. Increase in diameter of powder chamber.—The development of great velocity and power has been accomplished by the use of relatively heavy charges of powder in guns of great length.

And in order to keep the maximum pressure within reasonable limits (and thus avoid making guns too heavy and unwieldy) "slow burning" or "progressive powders" are used. If the powder chamber were maintained the same size as the rifled part of the bore, the cartridge would be too long and thus cause wave-pressures, which might endanger the safety of the gun. Wave-pressures are believed to occur only when very long cartridges are used; therefore the chamber must be greater in diamter than the rest of the bore in order to *reduce the length* of the cartridge for the same weight of charge.

10. Parts of a gun, as viewed from the outside: All guns have these parts, viz., the breech, muzzle, body or cylinder, and chase; and some guns, the base, trunnions, and elevating band.

(1) The *breech* is the rear end of the gun, while the *muzzle* is the front end. In the case of the old muzzle-loading guns "breech" used to be defined as the mass of solid metal to the rear of the bottom of the bore called "base," while the muzzle was that part terminating in the chase where there was increased thickness of metal.

(2) The *body* or cylinder, at the breech end of a gun, is that part over the chamber (and in high-power guns over part of the rifled bore) where the metal is the thickest. The outside diameter being about the same for the above distance gives rise to the name *cylinder.*

(3) The *chase* of a gun may be defined as the sloping portion forward of the cylinder extending to the muzzle, whether in one taper or in stepped tapers caused by hoops. In long high-powered guns, the end of the chase forms at the muzzle a curve of increased diameter, which is known as the "bell muzzle." The metal is increased at that point to give greater strength and thus prevent enlargement of the bore due to high muzzle pressures from smokeless powder. It is easily seen that the metal at the end of a tube has not the same support as a section further to the rear.

(4) *Trunnions* are two cylindrical arms on the sides of a gun at right angles to the axis, at or near the center of gravity, to support the gun on the carriage. In cast guns the trunnions are in one with the gun, while in "built-up" guns they are carried

on a separate band. No gun, in our service, over 8 inches in caliber, has trunnions; some of the trunnioned guns of smaller sizes—even those that have been otherwise "converted"—are still in service, but the modern practice is to make the trunnions a part of the *slide*.

11. The object in rifling a gun is to give rotation to the projectile about its longer axis. Hence, of necessity, elongated projectiles are used in rifles.

(1) Rotation is necessary to prevent the shell from "tumbling;" to cause the shell to fly steadily point first.

(2) The principle of the rifle may be illustrated by a rapidly spinning top which stands upright. The projectile on leaving the muzzle of the gun has a velocity of translation, or onward velocity, and also a velocity of rotation about the longer axis.

12. Manner in which rotation is given.—In breech-loading rifles, rotation is accomplished by a copper rotating or driving-band which is pressed into an annular score in the body of the projectile near the base and is kept from turning by roughening the score; the band moulds itself into the grooves of the rifling as the projectile moves along the bore.

13. Definition of twist as applied to rifling: *Twist* is the term generally used to define the angle of inclination of the groove, at any point, to the axis of the gun's bore; or the pitch of the rifling; or the distance in which the spiral makes one complete turn. Hence rifling may be treated like a screw thread.

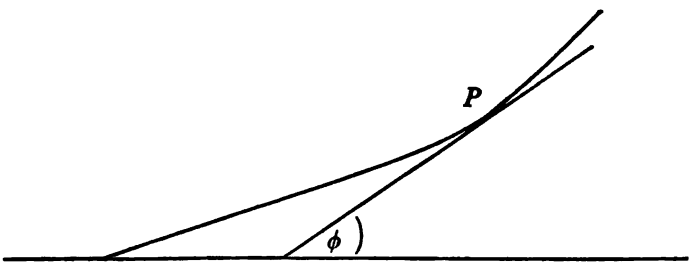
The latter method is generally used to describe rifling, and it is customary to use as a unit of measurement the caliber of the gun itself. Thus, one turn in 25 calibers for a 6-inch gun means that the rifling would cause the shell to revolve once around its axis while traversing a distance of $25 \times 6 = 150$ inches, in the direction of the axis.

14. Kinds of twist.—There are, (1) "uniform twist," or where the angle of inclination is the same throughout the bore; (2) "increasing twist," or where the angle of inclination constantly increases toward the muzzle. This twist may start from 0, or a small inclination, and increase to the full amount at the muzzle. Uniformly *increasing* twist is the one adopted for all modern United States Navy guns, and it usually increases from

o at the origin to one turn in 25 calibers at the muzzle. (3) Combined uniform and increasing twist (not used in our service except in some of the early 6-pdrs. and 3-pdrs.).

15. Measure of twist.—If the rifling of a gun be developed, each land will show as a curve as shown in the sketch. The angle ϕ which the tangent to the curve at any point P makes with the axial line is a measure of the twist of the rifling at that point. The twist is usually expressed as the tangent of the angle ϕ.

16. The forms of rifling grooves (see figure).—There are various forms, but only two are found in the United States Navy. They are called (1) "plain section" and (2) "hooked section"



CURVE OF RIFLING. ART. 15.

grooves. There are a *large number* of wide shallow grooves of equal width suitable for soft rotation bands.

(1) *Plain-section grooves* (Fig. 1) are those in which the bottom of each is concentric with the bore, the sides terminating in quadrants of a small circle, both alike. This form is used for many of the earlier guns below 6 inches in caliber, and is used on the Marks I and II 6-inch and 8-inch guns.

(2) *The hooked-section groove* (Fig. 2) is a shallow groove consisting of a *driving side,* the curve of which is a part of small circle (radius about 0.09 inch); then a small portion (about one-quarter) of the groove is concentric with the bore, while the remaining side is sloped off into the bore by radii and a straight taper, forming the *lands* between the grooves. By the *driving side* is meant that side of the groove which exerts the pressure on the rotating band; our guns being rifled with a right-handed

twist, the driving side is *on the right of the groove.* This is the more modern groove and is used for all the later main-battery guns and for most of the early ones.

(3) The depth of a groove is usually 0.05 inch (for large guns); the width usually decreases from the breech toward the muzzle, in order that the rotation band may completely fill the groove and thus prevent the escape of the powder gas around the projectile. If the grooves were not narrowed, the cutting away of the metal on the rotation band would leave a gradually increas-

FIG. 1. PLAIN SECTION GROOVES.

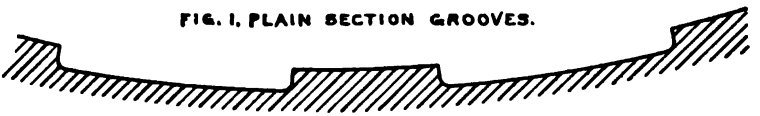


FIG. 2 HOOKED SECTION GROOVES.

FORMS OF RIFLING (ENLARGED). ART. 16.

ing space for the gases to flow through and thus produce erosion of the bore.

17. Uniform compared with increasing twist.—(1) Uniform twist is simpler; the *mean* pressure between driving surfaces is less, but the *maximum* pressure is greater than with "increasing twist." The maximum pressure between driving surfaces in uniform twist is greatest at the *start* and the band is more or less apt to strip for this reason.

(2) With "increasing twist" the *least* pressure is at the beginning of the projectile's movement, as the rotation band is not forced to take the whole twist of the rifling at once, while the

greatest pressure is at the muzzle. The rifling has a better grip on the band at the start. Thus it will be seen that "increasing twist" is more suitable for heavy guns, especially when large powder charges are used, giving high velocities.

(3) It should be noted, (a) that *powder erosion* is less with increasing twist, due probably to the fact that new metal of the band is constantly moulded into the grooves, thus preventing the escape of gas around the projectile; (b) a narrower band must be used with increasing twist than with uniform, on account of the constantly changing angle of the rifling.*

18. Windage means the space left between the outer surface of a projectile and the surface of the bore of a smoothbore gun or a M. L. rifle. The projectile in this case must be a trifle smaller in diameter than the caliber of the gun, in order to load easily.

NOTE.—In the case of smoothbore guns, as there is no rotation band on the shell, there must be some escape of powder gas on firing. It is not usual to say that a breech-loading rifle has windage, because the rotation band fills the space.

Guns Classed Aboard Ship.

19. The following is the usual shipboard classification: (1) Main-battery guns; (2) secondary-battery guns; (3) field-guns; (4) small-arms.

20. Main-battery guns.—All guns of and above 4 inches in caliber constitute the "main battery."

(1) The term "great guns" is an old one used for the main battery, arising probably from the weight or size of the guns, to distinguish from howitzers, etc. The term is still often used as an adjective, thus, "great-gun practice."

* It has been recently determined that these conclusions may be incorrect. With a *uniform twist* the maximum pressure between the driving surfaces is found at the origin of rifling, but it is not greater than the maximum pressure with an *increasing twist* and the total amount of energy absorbed is considerably less in the former case because of less frictional resistance. For the largest projectiles, rotating bands of sufficient width cannot be employed with rifling of increasing twist. The conclusion is, therefore, *that uniform twist is superior to increasing twist and is likely to be adopted in future construction.*

(2) Some small vessels, such as torpedo boats and destroyers, may not carry a gun as large as a 4-inch; in this case such as are carried constitute the "battery."

21. Classes and calibers of United States Navy main-battery guns.—The main-battery guns are divided into: (1) Heavy-caliber and turret guns; these are the 13-inch, 12-inch, 10-inch, and 8-inch guns. (2) Intermediate-caliber guns; these are the ordinary rapid-fire and B. L. types, represented by the 6-inch, 5-inch, and 4-inch guns (and the new 7-inch).

22. Definition of rapid-fire guns.—(1) A rapid-fire gun is a single-shot (single-barrel) gun of a greater caliber than small-arms, using "fixed ammunition," or a cartridge case, and having a quick-acting breech mechanism operated by a single movement of the hand.

(2) The short definition used by some is: A gun that uses a metallic cartridge case,—on the supposition that it is known that the breech mechanism is quick-acting.

(3) Strictly speaking, the gun-mount should be included in the definition. A mount permitting a quick and easy elevation and train, having practically a "run-out position" of the gun, is a *sine qua non.*

23. The term "quick-fire gun" was formerly used to designate guns with a quick-acting breech mechanism, *using powder in bags.* But as practically all B. L. Rs. are now supplied with quick-acting mechanisms, there is no longer any necessity for using the term "quick-fire," and *the term has therefore been abolished by the Bureau of Ordnance.* All guns are now classed either as "B. L. Rs." or "rapid-fire guns." The former use powder in bags and have gas-checks; the latter use fixed ammunition and have no separate gas-check.

24. Names of standard main-battery B. L. Rs. and rapid-fire guns:

(1) Four-inch rapid-fire, Dashiell, Fletcher, and Driggs-Schroeder; the new service-designed 50-caliber, 4-inch.
(2) Five-inch rapid fire, Dashiell and Fletcher.
(3) Five-inch Vickers, B. L. R.
(4) Six-inch rapid-fire, Fletcher and (one) Dashiell.

(5) Six-inch Vickers B. L. R. (and one experimental Fletcher).

(6) Also six-inch rapid-fire, with Bethlehem breech closure for the U. S. S. Baltimore.

(7) Seven-inch, Vickers, B. L. Rs.; eight-inch B. L. Rs.

(8) Turret guns; 8-inch, 10-inch, 12-inch, and 13-inch B. L. Rs.

25. Secondary-battery guns.—All guns, of whatever type, of a caliber less than 4 inches, and guns of small-arm caliber (not fired from the shoulder or held in the hand), such as machine guns, constitute the "secondary battery." Some small vessels carry nothing but "secondary-battery" guns. The term "minor-caliber" is sometimes applied to guns of a caliber less than 4 inches, and hence means a "secondary-battery" gun.

26. Definition of automatic gun.—This is one in which, the first shot having been fired by hand, the explosion of each cartridge successively and continuously operates the mechanism to eject the empty case and to load and fire another cartridge, so long as ammunition is properly fed.

27. Definition of semi-automatic gun.—This is a single-shot gun in which one operation of the hand is required for each round, the other operations being performed automatically by the explosion of the cartridge.

28. Definition of machine gun.—This is one of small-arm caliber (in a broad sense, a machine gun may be of any caliber, and the term is so used for the purpose of classification), from which a continuous rapid fire can be maintained, the operation of its mechanism, either by hand or by motor power, causing successively the loading, firing, and the extraction of the empty case, the ammunition being suitably supplied.

29. Names, types, and calibers of United States standard secondary-battery guns.—(1) *Rapid-firing guns.*—The 3-inch, 50-caliber (or 14-pounder guns); the 6-pounders, caliber 2.244 inches, Hotchkiss and Driggs-Schroeder; also, 3-pounders, caliber 1.85 inches, and 1-pounders, caliber 1.457 inches, of the same patents.

(2) *Semi-automatic guns.*—Maxim-Nordenfelt, and Driggs-

Seabury 6-pounders; Maxim-Nordenfelt and Hotchkiss 3-pounders; and Hotchkiss 1-pounders.

(3) *Automatic guns.*—Maxim-Nordenfelt 1-pounders, and Colt automatics of rifle caliber.

(4) *Machine guns.*—Gatling guns of rifle caliber; "revolving cannon" of 53-millimeter, 47-millimeter, and 37-millimeter calibers, firing projectiles weighing, respectively, 3.9, 2.4, and 1 pound. The revolving cannon are rather out of date and there are but a few in service.

30. Top-guns are a part of a ship's secondary battery mounted in the military tops on special "top mounts." The smaller-caliber guns, such as the 1-pounder rapid fire, 1-pounder automatic, Colt automatic, and Gatling guns are those generally used as "top-guns." *

31. Field-guns.—(1) These are light guns, usually of, or less than, 3 inches in caliber, mounted on "field carriages" for operations on shore. When of a single-shot or rapid-fire type, specially designated as "field," they are usually lighter in weight and shorter than the Navy gun of the same caliber.

(2) The secondary guns of a ship's battery, especially the 1-pounders, machine, or automatic guns, are, however, mounted on "field carriages" and used as field-guns.

(3) There are two types of "field-guns," (a) ordinary and (b) rapid-firing. The ordinary type is represented by the old 3-inch breech-loading rifled howitzer, of which a number are still in the service. The rapid-fire type is represented by the Fletcher 3-inch field-gun, firing a shrapnel (weight 12 pounds), and the 6-pounder Driggs-Schroeder field-gun.

32. Boat-guns.—These are the "field" or lighter guns of the secondary battery, mounted on special boat-mounts in a ship's larger boats, such as launches and cutters.

33. Small-arms are those fired from the shoulder or held in

* The practice of mounting guns in tops is likely to be discontinued. These positions are required for purposes of range-finding, range-transmission and fire-control. And it has been demonstrated that guns mounted in the tops are too small and too inaccurate to be of value at fighting ranges.

the hand. They are usually of a caliber less than .50 inch. The types are the rifle (musket), and revolver, or pistol.

(1) *The rifles* are the Hotchkiss magazine, of .45 caliber; the Lee-bolt magazine, .45 caliber; the Lee straight-pull, caliber 6 millimeters; and the United States magazine rifle, .30 caliber (Krag-Jorgensen). The two former are used only for sub-caliber practice.

(2) The *revolvers* used are the Colt's, and the Smith and Wesson double-action Navy, caliber .38, six shots. A few Colt's automatic pistols have been supplied.

34. Names, types, and calibers of foreign-built guns used in the service:

(1) Armstrong 6-inch rapid-fire (purchased with New Orleans and Albany).
(2) Vickers 6-inch B. L. R. (only one).
(3) Armstrong 4.7-inch rapid-fire (purchased with New Orleans and Albany).
(4) Maxim-Nordenfelt 4.7-inch rapid-fire (only two), Melstrom breech mechanism. Made by Vickers & Co.
(5) Welin 4.7-inch rapid-fire (only one). Made by Vickers & Co.
(6) Hotchkiss 14-pounder and 9-pounder rapid-fire guns.
(7) Maxim-Nordenfelt 3-inch, or 12½-pounder, rapid-fire gun, Melstrom breech mechanism (only one).
(8) Nordenfelt 6-pounder rapid-fire guns, Mark II.
(9) Maxim-Nordenfelt 6-pounder and 3-pounder semi-automatic guns.
(10) Maxim-Nordenfelt 3-pounder rapid-fire guns; Maxim 1-pounder automatic, and a number of English and French-built Hotchkiss 6-pounder and 3-pounder rapid-fire guns; French 1-pounder Hotchkiss guns; a few French-built Hotchkiss revolving cannon of 53-millimeter and 47-millimeter calibers.

35. A pneumatic gun is one in which highly compressed air instead of powder gas is used to propel the projectile. The construction is quite different from that of powder guns, the form being cylindrical, as the air pressure is not great. The only guns

in our service of this type are the so-called dynamite guns formerly used on board the Vesuvius; the system is unsatisfactory because the low velocity and consequent high trajectory makes accurate fire very difficult. The Vesuvius' guns have been removed, and the vessel has been converted into a torpedo training-ship.

36. Designation of guns.—Guns are usually named or designated either by (1) caliber in inches; (2) weight of projectile expressed in pounds (if not less than one pound); (3) the name of the breech mechanism or its character; (4) combination of (1) and (3) or (2) and (3). Sometimes these are followed by the length of bore in calibers, and an abbreviation for the "distinguishing terms," breech-loading, or muzzle-loading, rifle; or the special terms, rapid-fire gun (R. F. G.), breech-loading gun (B. L. R.), or the character of the ammunition.

NOTE.—Thus, for modern guns of or above 3-inch caliber, 6-inch 40-caliber B. L. R. means a 6-inch breech-loading rifle 40 calibers length of bore; 5-inch R. F. G., a 5-inch rapid-fire gun; 6-inch 50-caliber B. L. R., a 6-inch breech-loading rifle 50 calibers long; and 8-inch M. L. R., an 8-inch muzzle-loading rifle.

For old smoothbore guns, the number indicating the inches of caliber is written in the Roman style and no distinguishing term is used, thus, XV-inch gun.

For modern guns below 3 inches in caliber, 6-pounder H., means a 6-pounder Hotchkiss gun; a 6-pounder 50 caliber D. S. R. F. G., a 6-pounder Driggs-Schroeder rapid-fire gun 50 calibers length of bore; Maxim-Nordenfelt heavy 1-pounder, a gun firing a one-pound shell fitted with a Maxim-Nordenfelt breech action and using a heavy charge to distinguish from the same caliber gun using a lighter charge; Colt automatic gun, a gun with the automatic breech action of the Colt patent (see definition of automatic guns).

For small arms, the designation in our service has not followed any rule; 45-caliber Lee means a rifle of .45-inch caliber with a Lee breech mechanism; 6-mm. rifle, a rifle of 6-millimeter caliber with a Lee straight-pull breech mechanism; U. S. magazine rifle, a rifle of .30-inch caliber with Krag-Jorgensen breech mechanism.

In addition to the above, where there are different marks (see definition of term) of the same caliber, the following form or designation is sometimes used: 5-inch 40-caliber R. F. G., Mark III, or 6-pounder Maxim-Nordenfelt, Mark III. Some guns retain their foreign designation; 37-mm. Hotchkiss R. C., meaning a Hotchkiss revolving cannon, caliber 37 millimeters (1.456 inches).

The usual *service method* is to write the caliber and the mark only, thus, 8-inch Mark III; 6-pounder Mark II, Hotchkiss.

Power of Guns.

37. Previous to the year 1879 a muzzle velocity of 1350 to 1450 f. s. was considered good for a rifled-gun, and the penetration and ballistic properties of the gun were limited by those velocities.

(1) The introduction of slow-burning *brown powder,* and a considerable increase in the length of naval guns had the effect to increase the muzzle velocity to about 2000 f. s., which was the rule for several years.

(2) The comparatively recent perfection of smokeless powders marks the next increase in muzzle velocity. The absence of solid residue, after the combustion of smokeless powder, leaves more space for gases in the chamber. With the same, or even a smaller maximum pressure, about double the initial volume of gas is evolved, which, expanding to the muzzle (and being constantly augmented by the evolution of more gas from the slow or progressive burning powder), increases the pressure along the bore and gives to the projectile increased acccleration and a much greater initial or muzzle velocity.

(3) The new types of naval guns are designed for a muzzle velocity of 2800 or 2900 f. s.

(4) Still greater velocities have been attained in experimental guns.

38. Increase in power since 1879.—The power, or energy, of the projectile at any range increases as the square of the velocity; it is, therefore, evident that by increasing the muzzle velocity from 1450 f. s. to 3000 f. s. the muzzle energy is more than quadrupled with the same weight of projectile. Hence the term *high-powered guns* is applied to guns having an attainable muzzle velocity of about 2500 f. s. and upward, and the term is applied to guns of all calibers.

The Practical Principles of Gun Construction.

39. A high-powered breech-loading gun being a necessity, the question arises, how shall the gun be constructed?

40. A gun may be considered as a tube destined to withstand a given pressure from within, throwing a projectile which shall produce certain effects at given distances. In constructing such a tube, we must first consider what pressures it will have to withstand at the various points of its length, and then make it strong enough to insure perfect safety. The bore should also be of such material as to stand the wear and tear of firing a large number of rounds without being so damaged by expansion or abrasion as to interfere with the shooting.

41. Not only must the gun be sufficiently strong, but it must not be too heavy; so it is important that the material shall be arranged in such a manner that there may be no waste of its strength—in fact, so arranged that every part shall perform its own share in withstanding the pressure from within. Shortly after the shot begins to move, the pressure inside the gun decreases, and continues to decrease as the projectile approaches the muzzle; for this reason the gun is made stronger at the powder chamber than toward the muzzle end.

42. Stresses.—Looking simply to the construction of a gun cylinder, we find that the two principal stresses to which such a cylinder is subjected upon the explosion of a charge are, first, a circumferential or *tangential stress* or tension, coupled with a *radial stress,* tending to split the gun open longitudinally; second, a *longitudinal stress* tending to pull the gun apart in the direction of its length.

43. The least complicated method of making a gun would seem to be that of casting it as a homogeneous hollow cylinder; but if we take such a tube, made of one material throughout, we find that its tangential strength to resist a pressure from within does not increase uniformly with its thickness.

44. We find, practically, that with a given material we soon reach a limit beyond which *any additional thickness of wall aids but little* in enabling the cylinder to withstand pressure. Supposing the metal to be incompressible, this limit is taken at about half a caliber, so that—for example in the cylinder of an hydraulic press—if the thickness of the walls be equal to one-half the diameter of the piston which works inside, then the cylinder will be nearly as strong as if it were ten times as thick.

45. It is generally conceded that no possible thickness can enable a simple cylinder to bear a continued pressure per square inch from within *as great* as the tenacity of a square-inch bar of the same material; that is to say, if the tensile strength of cast iron be 12 tons per square-inch, no cast-iron gun, however thick, could bear a charge which would exert that pressure on each square-inch; for, on the first round the interior layer would be ruptured before the outer portion could come into play, and every succeeding round would tend to make matters worse.

46. From the above it is clear that guns made by casting iron, bronze, or steel into homogeneous cylinders cannot be made strong enough. The working pressure which we require a high-powered gun to withstand is not less than 18 tons per square-inch, and we require, further, that this pressure shall not strain the gun beyond the elastic limit of the metal, in order that the bore of the gun shall not be permanently enlarged. The elastic limit of cast steel is from 15 to 20 tons per square-inch, and we have seen that steel has a higher elastic limit than either iron or bronze, so that, allowing a margin of safety, it will not do to make a high-powered gun of cast homogeneous metal even when we use steel. We must resort, then, to what is termed the *built-up system*, and it can be shown mathematically that a built-up gun, properly constructed, of the same dimensions and material as a homogeneous gun, is much stronger than the latter.

47. A built-up gun is one in which the principal parts are separately constructed and then united in a peculiar manner; and guns so constructed may be composed of different kinds of metal, or of the same kind of metal throughout. We now come to the two principles of construction for strong and heavy guns.

48. First—The principle of varying elasticities.—This consists in placing that metal which stretches most *within its elastic limit* around the surface of the bore, so that by its enlargement the explosive stress is transmitted to the other parts exterior to it. This method is exemplified in guns which have a steel tube surrounded by wrought-iron coils, and in the Palliser system, in which a wrought-iron or steel tube is surrounded by cast iron. With different grades of steel—high and low steel, for example—the steel which shows the greater elongation within the elastic

limit is the more suitable to be placed next to the bore. Carrying out this theory in practice is another matter, because in the case of very long tubes there is more difficulty and uncertainty of manufacture with the higher grades of steel than with the lower, and the difficulty increases with the size. *For this reason the principle of varying elasticities is only applicable where the different parts of a gun are made of different metals.*

49. Second—The principle of initial tensions.—This consists in giving to the exterior portions of the gun a certain initial tension, gradually increasing toward the interior, and giving to the interior parts a certain normal state of compression by the grip of the outer cylinders and coils.

50. If by the system of initial tensions the interior can be put in a state of compression, within the elastic limit of the metal, the amount of that compression is so much additional strength, since it must be first overcome before the powder gases can exert a tension on the fibers of the interior tube. In order to exert compression, then, the outer coils or hoops must be in a state of normal tension, and in addition to that they must have a margin of strength within their elastic limits to withstand the additional tension transmitted by the explosion of the charge, this additional tension being, of course, much less than would be put upon *free* metal next the bore.

51. The exact amount of tension and compression for all parts of the gun when at rest, or when resisting the explosion of the charge, so that all parts shall be strained to a point not exceeding their elastic limits, is a matter for mathematical calculation, and is treated at length in works on the theory of gun construction.

52. The principle of initial tensions, carried to an extreme limit, would be exemplified in the case of a gun composed of an infinite number of infinitely thin hoops properly shrunk together. When so assembled, the tension in a gun, when the powder pressure acts, would be uniform throughout the thickness. The greater the number of hoops the nearer this theory is approached in practice, but there are practical difficulties in manufacturing, such as the accurate machine work necessary and the greatly increased cost; for this reason it is not considered practicable to use more than four layers in the case of guns now designed. In the case of wire

guns, or ribbon-wound guns, this theory is better exemplified, and when successful manufacture is possible in these cases, stronger guns of the same weight must be the result.

53. The principle of *initial tensions* is followed in all built-up guns for the Navy. And as all parts of the gun are made of high-grade steel, it is practically impossible, in following the principle of initial tensions, to secure, also, the advantages of varying elasticities, because the tube being much larger than the jacket and the jacket much larger than the hoop, the elastic strengths of the several parts will vary inversely as the size, and thus the principle of varying elasticities will be violated.

54. Shrinkage.—Practically, the compression of the interior and tension of the exterior is effected in manufacture, after the amounts for each have been calculated, either (1) by *shrinkage,* (2) by forcing two cylinders of slightly coned surfaces upon one another by hydraulic pressure, or (3) by winding steel wire, or riband, over a steel tube.

55. If the method of shrinkage be employed, the hoops or tubes to be shrunk on must be accurately bored, and the outer coil expanded by heat until it is sufficiently large to slip over the inner coil or tube. The inner diameter of the outside coil when cold must be a little smaller than the outside diameter of the inner tube, and this difference of diameters is called the *shrinkage.* While the outer coil is cooling and contracting it compresses the inner one, making the diameter of the latter a little smaller than before. The amount by which the exterior diameter is decreased is called the *compression.*

56. Again, the outer coil itself is stretched on account of the resistance of the inner one, and its interior diameter is slightly increased. This increase is called the *extension.*

57. The *shrinkage* is always equal to the *compression* plus the *extension,* and the exact amount must be previously calculated by the known extension and compression of various metals under certain stresses and given circumstances.

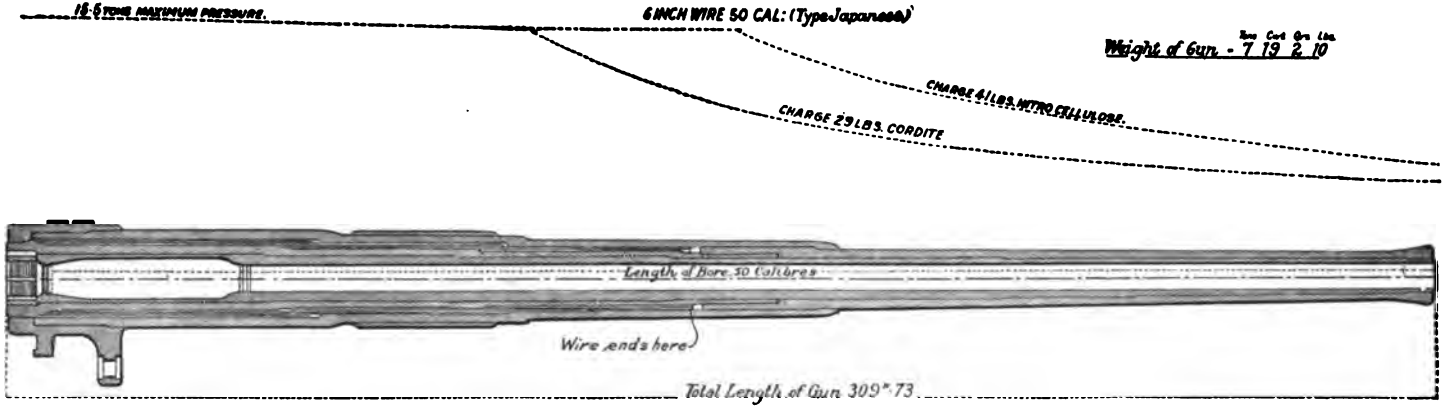
58. The thickness of walls.—Having settled upon the built-up gun as the proper construction to follow, it only remains to describe in general terms how the thickness of the walls is determined.

59. Experiments with crusher gauges placed at different distances along the bore of a gun, and formulas for constructing pressure curves, have enabled gunmakers to form a good idea of the pressures at different distances from the bottom of the bore. Hence a curve of pressures can be constructed for a given powder that will approximate to the truth for practical purposes; a good margin of safety is always allowed, and the various thicknesses of metal to withstand the pressures at different points of length of bore follow at once, the caliber and length of gun having previously been fixed by the amount of work the gun is expected to perform.

60. After the preliminary drawing of the gun has been completed, the elastic strength to resist powder pressure is computed at all points, together with the shrinkages. The strength curve is then compared with the pressure curve, and if there is not a sufficient margin of safety, a readjustment of the dimensions of the parts of the gun is then made, and the elastic strength is recomputed. It is also necessary to compute the stresses which the parts undergo in the *state of rest* to determine that the tube will not be crushed by the shrinkage.

61. Built-up guns in the service.—These comprise all guns of the main battery and the larger part of the secondary battery. The 6-pounder and 3-pounder Maxim semi-automatic rapid-fire, 1-pounder Maxim automatic rapid-fire; 53-millimeter, 47-millimeter, and 37-millimeter revolving cannon, are *single* forgings. The other secondary-battery guns consist of three parts, the tube, the jacket, and the locking hoop, which is generally screwed on.

62. The wire-wound gun.—As stated above, this is an example of the "initial tension" system. The wire is wound in layers around an inner tube of steel. Each layer is wound with a different tension of the wire, and each exerts a compression on the layers which are inside of it. The result is that, when completed, the outer layers are in extension, gradually diminishing to the inner layers, which are in compression; all within the elastic limit. As wire can be made of enormous strength (as much as 200,000 pounds per square-inch tensile strength), this type of gun is the strongest for the same weight of any yet developed.


18·6 TONS MAXIMUM PRESSURE.
6 INCH WIRE 50 CAL: (Type Japanese)
Weight of Gun - Tons Cwt Qrs Lbs. 7 19 2 10
CHARGE 41 LBS. NITRO CELLULOSE.
CHARGE 29 LBS. CORDITE
Length of Bore 50 Calibres
Wire ends here
Total Length of Gun 309".73

FOREIGN WIRE WOUND GUNS. Art. 67.

Ballistics.	Cordite.	Nitro-Cellulose.
Weight of Projectiles.....	100 Lbs.	100 Lbs.
Weight of Charge.....	29 "	41 "
Muzzle Velocity (Ft. Secs.).....	3000 "	3000 "
Muzzle Energy (Ft. Tons).....	6240 "	6240 "

63. In the different types of wire-wound guns, the inner tube may be either one piece of steel, or a number of longitudinal bars of special shape like the staves of a barrel gripped together by the wire to form a tube. As narrow bars can be made stronger than one large forging, this "stave" or *segmental wire-wound gun* is supposed to represent the highest type of built-up gun, and will stand enormous pressure (35 tons per square inch or more). The rifling is cut in a very thin liner which is next inside the segments.

64. The usual method of building wire-wound guns is to have a solid forging for the tube, stepped at the rear end, the wire being wound only over the parts covering the chamber and the rear end of the rifled bore. Ordinary hoops are shrunk on over the chase, and an outer hoop or hoops, also shrunk on, cover the wire-wound part.

65. *There are no wire-wound guns in our service.* There are some difficulties incident to the manufacture, and other drawbacks as to protection of wire, defective *longitudinal* strength, etc., which make this type, on the whole, less satisfactory than the ordinary hooped gun. A good many wire-wound guns from 5 to 12 inches in caliber are found in the English service.

66. Foreign wire-wound guns.—The 12-inch, 40-caliber, wire-wound gun of British type is constructed with two tubes, one inside the other, extending the whole length of the gun, thus admitting of rapid and efficient repair when the inner tube is worn out or injured. The radial strains on firing are overcome by the shrinkage of the outer tube over the inner, and by winding wire at varying tensions over the outer tube from the breech to a point near the muzzle. The jacket and a long chase hoop are then shrunk on over the wire to confine it, and are locked together. The longitudinal strain is taken by connecting the outer tube (in which the breechblock houses) to the jacket by a breech ring.

67. Plate I shows the 6-inch, 50-caliber, wire-wound gun constructed by Vickers Sons and Maxim for the Japanese government. It will be seen by reference to this diagram that the wire only extends for about one-half the length of the shot-travel, the radial strains in the chase being taken by a solid steel hoop shrunk over the inner tube. In guns of 50 calibers length, the elimination of the wire over the chase enables the girder strength to be

somewhat improved so that there is no fear of the extra length causing the gun to droop. It will be seen that the breechblock houses in the outer tube, and that the latter is connected by a large breech ring to a jacket which is shrunk on over the wire and securely locked to the chase hoop. By this system of construction great longitudinal strength is secured.

68. Nickel steel v. wire winding.—Messrs. Krupp, who have done so much for the improvement of ordnance generally, use nickel steel for all the tubes except the inner. The use of nickel steel instead of ordinary steel has no doubt some advantages, notably greater strength of material; but this high quality of steel is not so necessary with wire-wound guns, owing to the extra strength given by the wire far exceeding that of any ordinary nickel steel. There is much in favor of using a steel giving a high elastic limit and good elongation for the smaller types of guns, for which the wire system is perhaps less suited. By using suitable steel and treating it by a special process the necessary strength can be obtained without the addition of nickel.*

69. An effort is now being made to obtain a greater hardness for the metal next the bore to enable it to better withstand the erosion of smokeless powder. This may be done even at the expense of reducing the elongation of the metal.

* General Information Series No. 21, July, 1902.

CHAPTER III.

CONSTRUCTION OF NAVAL GUNS.

Revised by Lieutenant BYRON A. LONG, U. S. N.

1. Preliminary.

1. Parts of a gun.—A modern built-up gun is composed of a *tube*, a *jacket*, and *hoops*.

(1) The *tube* is in one piece and extends the entire length of the bore. It contains the rifled bore and the powder chamber.

(2) The *jacket* is immediately over the tube and extends well forward on it. Its rear end contains the screw-box.

(3) *Hoops* over the forward part of the tube are called *chase hoops*.

(4) *Hoops* over the jacket are called *jacket hoops*.

(5) *Locking hoops* are those which hold two adjacent parts together. The inner one is shrunk on and the outer one is screwed on.

2. Material.—(1) Tube, jacket, and hoops are made of open-hearth steel, fluid-compressed, forged, oil-tempered, and annealed. The steel used is of the best quality and is either plain steel or nickel steel, depending on the specifications. The forgings are furnished by the steel makers to the Naval Gun Factory, Washington, D. C., rough-bored and turned to dimensions fixed by the Bureau of Ordnance, Navy Department.

(2) The physical characteristics of each forging are determined at the steel works, in the presence of the officer on duty at the works.

(3) The chemical composition of the steel in each forging is also known to the officer, and each forging that is accepted bears his initials. This acceptance is only preliminary and, should any flaws develop later, the forging may be rejected. Each forging is also stamped by the steel works with a number which refers to the composition of the steel, method of manufacture, etc. Should these marks be removed in machining they are transferred else-

where. In addition to these two marks a third, the initials of the inspecting officer at the gun factory, is added during the process of manufacture. These three marks are on every forging in a gun.

(4) Every part of the breech mechanism is made of forged steel of known physical properties. There are a few exceptions to this in different guns but the parts excepted are those the failure of which would not prove serious, such as plug-trays, hinge-plates, carriers, etc. These are made of cast steel or bronze.

(5) In general we may say, then, that the gun and all its parts are made of forged steel.

3. Receipt and Assignment of Forgings.—(1) Forgings, when received at the gun factory, are weighed, carefully examined for the marks of the steel works and the inspecting officer, and no work is to be done unless these marks are found. The forgings are measured to ascertain if they are of proper dimensions to work out to finished drawings. A careful examination is made for gouges, etc., or for any defects not likely to disappear in finish-machining. An inspection is made to see if the forgings are warped. If a forging is found badly warped it is returned to the steel works to be straightened. All doubtful points arising are referred to the Bureau of Ordnance for final action.

(2) All data concerning each forging are entered in a rough forging book and the assignment of forgings for guns serially is now made and placed on each forging. Care is taken in the assignment to have all the forgings in any gun from the same steel works, if possible. A careful record is kept of the forgings put in each gun, the forgings being identified by their marks.

(3) All the above work is done under the supervision of an officer, responsible to the superintendent of the gun factory.

4. Setting the Forging in the Lathe.—(1) The forging is brought to the lathe by a crane and one end—the breech, for instance—is gripped by 4 to 6 large jaws on the face-plate. The muzzle-end is likewise gripped by a pot-center, a large iron ring having several arms screwing through it radially.

(2) The forging is now on live centers. By revolving the forging and screwing the jaws of the face-plate in or out the breech can be centered as shown by the mark of a tool on the surface of the forging.

(3) The muzzle-end is similarly centered. Then the forging is revolved while the tool is run along on its carriage. This is done to see whether the forging is warped. Should it be warped the screws at each end are moved so that the work is thrown to one side or the other to offset the warping. A surface is now turned near the muzzle-end for a steady-rest. In all long work one or more steady-rests are used to prevent springing, and, of course, steady-rests have to be used in boring. The steady-rest is placed in its bearing and the pot-center removed. With the pot-center removed, the balancing-rod can be inserted and the eccentricity of the bore noted. It may be necessary to throw the forging to one side or the other to allow for eccentricity in the bore. In all cases the forging must be centered so as to have sufficient metal both inside and out. When the direction is finally determined, the steady-rest surface is trued up, if it has been thrown out, and surfaces turned for additional steady-rests.

(4) A bearing is also bored out at the muzzle-end. If the forging is to be bored, nothing more has to be done, except possibly to add another steady-rest. If it is to be turned, a dead center is first placed in the bearing just bored and the steady-rests retained if desirable.

(5) In both turning and boring the work revolves and the tools are fed along.

5. Turning.—This operation is comparatively simple. The work is set in the lathe and revolved while the tool, held in a carriage, is fed along. Sometimes as many as four tools are cutting at the same time, using two or more carriages. For finishing-cuts tools 1 to 2 inches wide are used. There is no difficulty in keeping measurements to .001 of an inch. Steel snap-gauges are used to get the diameters. These gauges are previously set by steel points of known lengths.

6. Boring.—(1) Boring requires greater care than turning. In turning, the work is before the man at all times and the action of the tools can be observed and as many measurements taken as desirable. After the tool is started in boring, the workman can not tell what is happening unless he removes the boring-bar. It is found impracticable to bore a cylinder to accurate dimensions with the ordinary tool on the end of a bar, because of the spring

of the bar. For this reason bits are used. These bits are simply tools on the ends of long cylinders. The cylinders give the tools rigidity and, as they fit the bore closely, make the direction accurate. In order to make accurate bearings for these bits, 3 to 6 inches of the bore is first cut out with the ordinary tool.

(2) Two kinds of bits are used, hog-bits and packed-bits (see Figs. 1 and 2). Hog-bits are for rough cuts and are half-cylinders of cast iron with one tool. Packed-bits are for finer cuts and are full cylinders of wood with iron frames. They have two tools, 180 degrees apart. The wood is slightly larger than the hole that the bit is cutting so that the tools are held rigidly and accurately. Even with the best workmanship the boring cannot be kept within .001 of an inch. Errors creep in due to wear of tool, eccentricity of bit, spring of metal, etc. It is for this reason that in gun con-

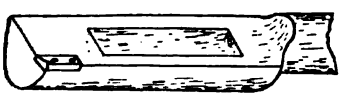


FIG. 1.—HOG-BIT. ART. 6.

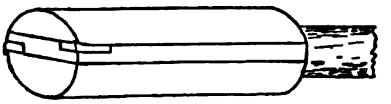


FIG. 2.—PACKED-BIT. ART. 6.

struction the jacket or hoop to be shrunk on is always bored first, and, from the dimensions found, the outer diameters of the tube or partly built-up gun are determined.

(3) For boring an ordinary hoop three cuts would be required, one cut with a hog-bit and two cuts with packed-bits. The rate of cutting is very slow, being from 2 to 6 inches an hour, depending on depth of cut, size of forging, etc. The bits are kept well lubricated in oil. The bore is inspected for flaws after each cut.

(4) In boring tubes or long hoops it is customary to reverse the work in the lathe after it has been bored half way. This is done to prevent the bit from "running out," and is done only on hog-bit cuts. As soon as an accurate hole has been bored by the hog-bit there is little danger of the packed-bit "running out," and the packed-bits are run all the way through.

(5) Short hoops of large diameter would require very large bits. It is found more convenient to bore these hoops with a boring-bar.

7. Balance-rod or indicator.—To ascertain whether a hole has been bored true with the line of dead centers, a simple device known as a balance-rod or indicator is used. This device consists of two wooden rods joined together end-on by a right-angled strap of iron. One rod, the one which enters the bore, has a small roller on its end. The other rod holds a pointer. The rod is inserted in the bore and balanced on a knife-edge under the iron strap, the roller resting on the bore. A vertical stand is placed so as to record the marking of the pointer. A zero point is first marked by the pointer and then the work is slowly revolved. Should the hole be eccentric the pointer will move up or down and serve as a means of indicating the amount of eccen-

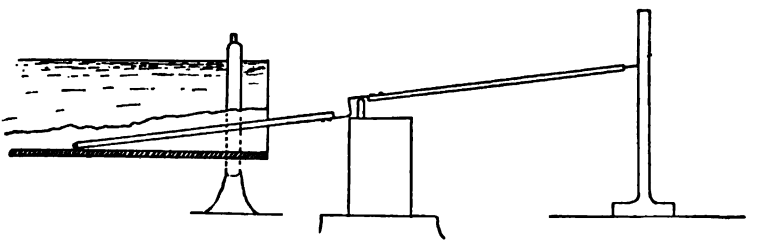


FIG. 3.—BALANCE-ROD OR INDICATOR. ART. 7.

tricity of the bore at the point where the roller is. These indications are taken every two feet. A long forging that is being bored will be indicated about three different times during a cut to see whether the bit is running true. Should the bit be running out, the centers are thrown and the bore trued up with a slightly larger bit. After an accurate hole has once been bored there is little danger of the bit running out in succeeding cuts (see Fig. 3).

8. Bore-searching.—(1) Every forging, when finish-bored, is bore-searched, and all bore-searching is done by officers. The bore is also inspected after each cut by a foreman with an electric light.

(2) The bore-searcher is simply a wooden frame, holding a mirror inclined 45 degrees to the axis of the bore. Three incandescent electric lamps furnish the light and a hood is provided on the frame to obscure the direct light from the observer. The

bore-searcher is moved slowly through the bore by a long wooden handle. About 90 degrees of the bore is illuminated at once, and four lightings are required completely to search it.

(3) Especial attention is given to any discoloration, cracks, streaks, or any flaws that may have developed in the finish-boring (see Fig. 4).

9. Star-gauge.—(1) The star-gauge is used to accurately measure the inner diameters of any long cylinder. This instrument is a graduated brass or steel tube, built in sections so as to be adapted to any length of work. It carries a head and a handle.

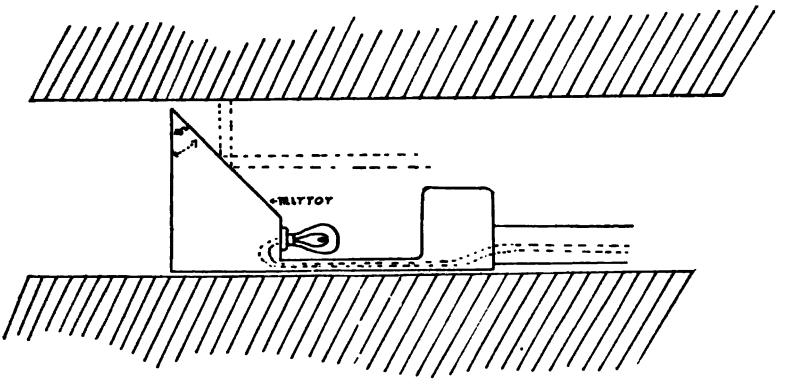


FIG. 4.—BORE-SEARCHER. ART. 8.

(2) The head contains three sockets, 120 degrees apart, pressed upon a coned rod by springs. Into these sockets are screwed points of lengths suitable to the work to be measured. The coned rod is simply the extension of a rigid steel rod passing through the tube and securing to the handle. Any forward movement of the handle causes the points to be pressed out a known amount, which is read from a scale on the tube and a vernier on the handle.

(3) The star-gauge is always adjusted before use by trying the points on a ring of known diameter. A set of rings of different diameters is supplied with the instrument. By adjusting the position of the handle the scale is made to read zero when all three points just touch the ring. In measuring the diameters of the bore the readings of the scale must be applied to the diameter of

the test-ring to get the correct diameters. The bore, whether of forging or of gun, is star-gauged at each inch of length and the powder chamber at each half-inch. The points are first set thus, ⊗ and then a second series of readings is taken with the points reversed, thus: ⊗

(4) In star-gauging the gun, after it has been rifled, guides are used on the head. These guides follow grooves and thus keep the points always on the same lands or in the same grooves. On the muzzles of all our guns the letter "s" will be found in four places. From the positions of this letter the lands and grooves which were star-gauged are known. Double readings are taken of both lands and grooves, the second reading being with the points reversed.

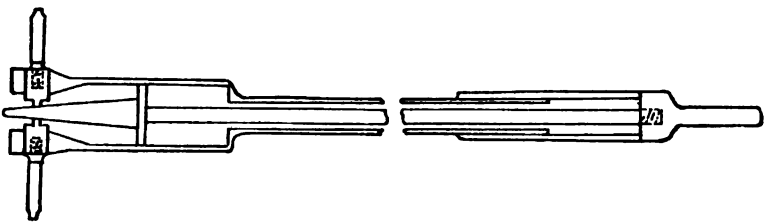


FIG. 5.—STAR-GAUGE. ART. 9.

(5) The readings of the star-gauge are correct to the .001 part of an inch. The record of every star-gauging, whether of gun or of forging, is kept on file (see Fig. 5).

10. Shrinkages.—The shrinkages for the different parts are prescribed by the Bureau of Ordnance. These shrinkages are computed, and are the same for one type of gun if the material used in the different guns of that type is of about the same strength. The different layers of a gun have different shrinkages, and the shrinkage in any one layer is not necessarily the same throughout.

11. Measurements.—(1) The figured dimensions on drawings are used. The rear face of the tube is taken as the origin for all measurements.

(2) In all machining the workman is furnished with the necessary gauges, graduated rods, and steel points for the dimensions

on his drawings. All measurements originate in the measuring department and all gauges are frequently referred there for verification.

(3) In general, diameters are given in thousandths of an inch and lengths in hundredths. Certain tolerances are allowed in machining and these are never exceeded.

(4) Outside diameters are measured either with snap-gauges or with beam-calipers. Inside diameters, with steel points or the star-gauge (see Fig. 6).

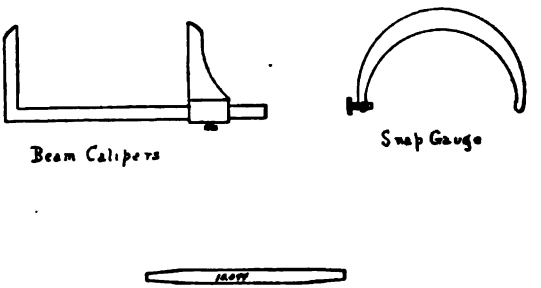


FIG. 6. ART. 11.

2. Building-Up the Gun.

12. Jacket.—(1) The jacket is the first forging worked upon. It is set in the lathe for boring and bored out to exact dimensions. This usually requires a cut with a hog-bit and two cuts with packed-bits.

(2) The forging is then faced and rough-turned. It is inspected for flaws outside and then removed from the lathe and bore-searched. Every streak or split is noted. It is star-gauged at each inch of length and the record preserved. The length is divided into four parts by cuts on the outer surface and these distances measured and the outer diameters calipered. These divisions and diameters are again measured and calipered after assembling to note what extension has been given to the jacket, and to see if the contraction has been uniform.

(3) From the star-gauging of the jacket a sketch is made

showing the exterior diameters of the tube under the jacket. These diameters are equal to the inner diameters of the jacket plus the jacket shrinkage, so that the extra metal is left on the tube. This sketch is used by the workman in turning the tube to finish-dimensions, preparatory to shrinking on the jacket.

13. Tube.—(1) The tube is set for turning and a rough cut taken off. This is done to take the spring out of the metal. It is then set for boring, and the bore is cut out to within .25 of an

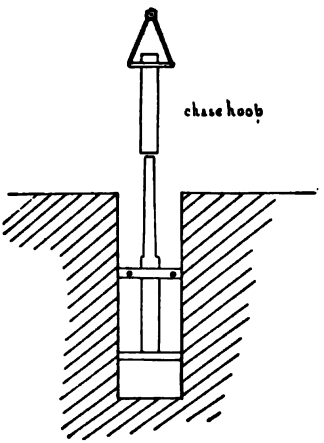


FIG. 7.—SHRINKING PIT. ART. 14.

inch of finished diameter. This amount of metal is left until the gun is completely built-up, and is removed in the finish-boring. The tube, of course, is reversed during the cut of the hog-bit, and indicated as often as necessary.

(2) The tube is again set for turning, faced off true, and turned for the length of the jacket to shrinkage dimensions, the tolerance being but .001 of an inch. It is inspected while in the lathe by an officer who assures himself by numerous measurements that the shrinkage surface is of the correct dimensions, and that no flaws exist in the metal. The tube is then removed from the lathe and bore-searched and star-gauged. Tube and jacket are now ready for assembling.

14. The Shrinking-pit.—The tube is placed in the shrinking-pit, breech-end down. (Some designs require the jacket to be

shrunk on from the breech-end. In building these guns the muzzle-end of tube would be placed down.) The shrinking-pit is simply a well of square section having two movable tables. The breech-end of the tube passes through the upper table and rests on the lower one, and the tube is then lined up vertically by four adjusting screws in the upper table. These tables may be moved up or down independently and adapted to any length of work. Water is circulated inside of the tube to keep it to normal dimensions and to assist later in cooling (see Fig. 7).

15. Hot-air furnace.—(1) The jacket is next lowered, breech-end first, into a hot-air furnace. This furnace is a vertical cylinder built in sections to suit the particular lengths of jackets, and is made of fire brick and asbestos. Heat is absorbed from air which has been passed in pipes over petroleum burners. The hot air enters at the bottom of the furnace, passes through and around the jacket, and out through a large pipe in the top section for reheating, the overflow being regulated by a damper. The temperature of the furnace is shown by a pyrometer let in the furnace cover.

(2) Air heating is regular and practically no local heating or warping occurs. Furthermore, the jacket is kept free from dirt. The heating takes place gradually, a large jacket requiring 30 hours to attain the required temperature. Every precaution is taken to keep the heating uniform throughout. The temperature of the furnace is raised gradually and kept between 600 degrees and 700 degrees F. The coefficient of expansion of steel up to 600 degrees may be taken as about .0000075 for 1 degree F. On a 16-inch diameter a temperature of 600 degrees would give .07 of an inch expansion. If the shrinkage is .02 of an inch there would be a clearance of .05 of an inch. The expansion is not allowed to exceed .005 of an inch for each inch of diameter.

(3) While the jacket is in the furnace its diameter is tested by lowering steel cross-points into it. The lengths of these cross-points are equal to the original diameter of the jacket plus the desired expansion.

16. First assemblage.—(1) When the jacket has received the desired expansion it is hoisted out of the furnace and again tried for diameters with the cross-points, previously checked. Occa-

sionally the temperature of the outer surface of the jacket is tested at the top, middle, and bottom before assembling by rubbing on it strips of alloys, the melting points of which run from 480 to 600 degrees. This test is made to ascertain if the heating has been uniform throughout. The bore is then wiped out with a moist muslin sponge. The jacket is swung over the pit and carefully lowered over the tube until it brings up at the proper point. It is guided by men with asbestos gloves and wet cloths, and turned to assist in centering it. A cold spray from a perforated ring of pipe is at once turned on where it is desirable to have the jacket grip first, such as at a shoulder. The rest of the jacket cools unassisted, but water is constantly circulating in the tube.

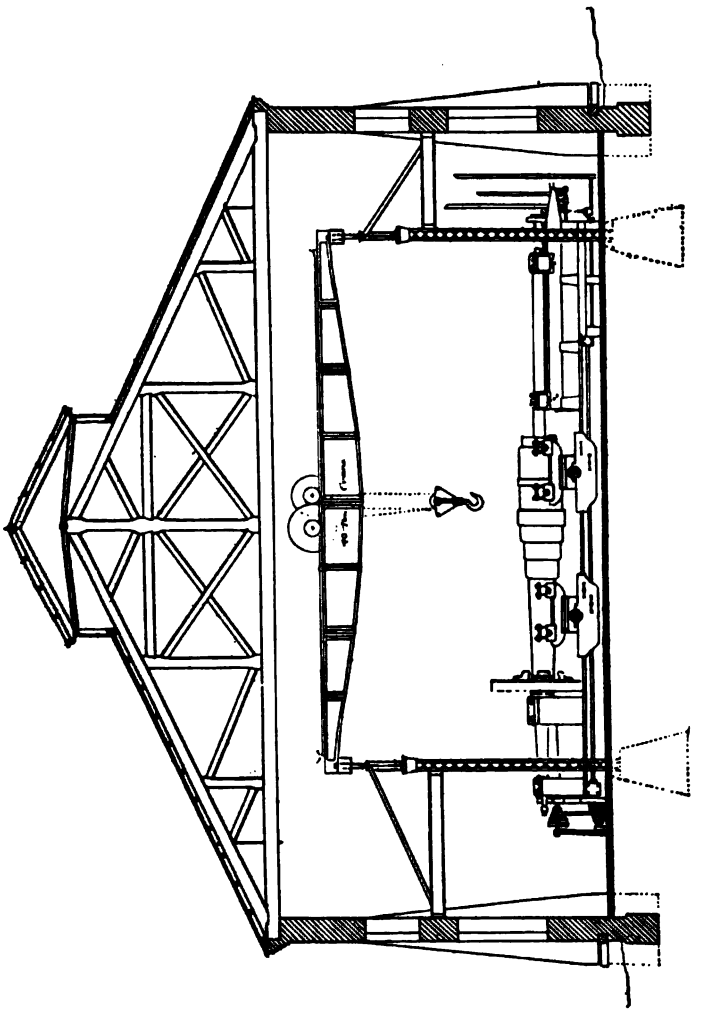
(2) Should the jacket "gall" or stick while being lowered, it is at once hoisted off and allowed to cool. The abrasions are filed off and after another heat has been given to the jacket a second trial is made.

(3) When the gun is quite cold it is hoisted out of the pit and measurements taken on the jacket to see if it has suffered any undue expansion or elongation. The contraction of the tube is also measured and then the tube is star-gauged under the jacket to note the compression due to shrinking on the jacket.

17. Second assemblage.—(1) The chase hoop next forward of the jacket is bored out, bore-searched, and star-gauged. From the star-gaugings and the assigned shrinkages the outer diameters for the tube are determined. The assembled tube and jacket are put in the lathe and the tube turned to proper dimensions and the jacket faced off. The surface of the tube is inspected by an officer for flaws and verification of shrinkage dimensions, as before. The partly assembled gun is returned to the shrinking-pit and the chase hoop is placed in the furnace. The hoop is shrunk on in the same manner as the jacket, over the muzzle-end of the tube, and the cold spray is applied at the joint of the hoop and jacket.

(2) When cold, the gun is removed from the pit and star-gauged under the hoop for compression due to the hoop. The contraction of the tube is also noted.

18. Successive assemblages.—(1) A locking hoop is next prepared and shrunk on over the joint between jacket and chase



TRANSVERSE SECTION OF 8-INCH GUN SHOP,
Showing Gun in Lathe.

hoop, binding these parts together. This hoop will be seen on reference to the drawings.

(2) This process of boring, bore-searching, star-gauging, and shrinking-on hoops is continued until the gun is completely built-up. The hoops are shrunk on in the most convenient order, but a second hoop is never shrunk on until the gun is quite cold. The gun is not placed in the pit for shrinking on short hoops, but is placed horizontally on skids and the hoops put on over the end. The contraction of the hoop is followed up in this case by forcing wooden braces against its free end by means of long tie-rods and nuts, set up at the breech. Some short hoops are put on while the gun is in the lathe.

(3) After each layer of hoops has been shrunk on, the gun is star-gauged and the compression noted. Should anything abnormal develop at any time during the process of building-up the gun, it is referred to the Bureau of Ordnance. The gun is considered completely built-up when the last hoop to be shrunk on is in place. The gun is now ready to be finished.

3. Finishing the Gun.

19. Finish-boring.—It will be remembered that .25 of an inch of metal was left in the tube in the original boring. The gun is now placed in the lathe and the bore brought down to finish-dimensions with packed-bits, great care being taken to get the bore straight. The balance-rod is used to test the accuracy of the final boring.

20. Finish-turning.—(1) In the large guns finish-turning is sometimes carried on while finish-boring, but this is not entirely satisfactory, as the speed best suited for turning is slower than that required for boring. This may be allowed for in some lathes by giving the boring-bar independent revolution so as to increase the virtual speed of revolution of the gun.

(2) The workman is provided with a finish-drawing, and the various tapers and fillets and the shoulder of the yoke are cut and a thread for the locking hoop chased and the latter screwed on. The breech is faced off true, leaving the screw-box of the correct length.

(3) For convenience, the bell-muzzle is left in the rough so that it may be gripped by the jaws of the face-plate in succeeding operations. The smooth finishing of the outside is done by file after the gun is about completed.

(4) Some small guns have a sleeve screwed on over them. The left-handed thread for this sleeve is chased during finish-turning.

21. Chambering.—(1) The chamber is still of the same diameter as the rest of the bore. It is first roughed-out with a hog-bit, followed by packed-bits. The finished chamber is of greater diameter than the entrance to it, so that the bits have soon to be replaced by a boring-bar. This boring-bar has a bearing in the bore, just forward of the powder chamber, and a guide in the screw-box. The cutting tool is set out the desired amount by gearing working inside of the bar. The slopes are cut either by hand feed or automatically, and the chamber brought up to finish-dimensions.

(2) In guns using cartridge cases the powder chamber is cut out to the required form by packed-bits. The finishing packed-bit carries a long tool set to the correct taper. The chamber is inspected by fitting in it a dummy case of the exact form of the chamber.

22. Bore-searching and star-gauging.—(1) The gun is now carefully bore-searched for any defects that may have appeared in finish-boring or chambering, or for any tool-marks, rough spots, etc.

(2) The bore and chamber are then star-gauged, the former for each inch of length and the latter for each half-inch, and the record preserved.

23. To chase the thread for screw-box collar—The bell-muzzle.—(1) In all guns from 4-inch to 10-inch inclusive, the screw-box threads are now cut in a separate collar instead of in the jacket as was formerly the practice. This collar is threaded on its outer surface and screws into the jacket. This operation of chasing the thread in the jacket is the one now carried out.

(2) *The screw-box* is first bored out to finish-dimensions and then the thread is chased in the ordinary lathe. The point for beginning the thread is plainly marked so that the collar will bring up in the right place. The thread is tested for accuracy by

screwing in a dummy collar. Any defect can easily be remedied while the gun is in the lathe. The practice of fitting screw-box collars makes it possible to replace a collar at any time should the threads become burred or worn in service.

(3) *The bell-muzzle* is now finished and the gun faced off to correct length. In guns that are hooped to the muzzle, the tube projects about .25 of an inch beyond the end of the hoop.

24. Chasing Welin thread.—(1) In the Welin form of screw-thread, which is now used in all main-battery guns, the thread is cut on arcs of different radii, as is fully described in Chapter IV. The screw-box collar is first marked off into the desired number of segments, and these segments are then cut out to the correct depths by a slotting machine. There is a small clearance left between the stepped segments. It remains now to chase the screw-threads.

(2) The collar is placed in the lathe and revolved. The point for beginning the thread is plainly marked. The tool, cutting the threads, is guided by a cam and is held against the cam by strong springs. As soon as the thread has been cut on one section, the cam automatically withdraws or extends the tool to the correct radius for cutting the thread on the next section. The clearance between the stepped sections is necessary to allow for the shift of the tool while the collar is revolving. The whole action of cutting is automatic and there is little danger of a careless workman spoiling the thread. The screw-thread may be either right-handed or left-handed. Turret-guns have threads chased oppositely for convenience.

(3) The thread on the outer surface of the collar is next chased and the collar is screwed into the jacket. It abuts firmly against the tube and is locked from turning by countersunk screws. This collar prevents the tube from moving to the rear.

25. Rifling.—Rifling consists in cutting spiral grooves in the surface of the bore from the compression slope to the muzzle-end.

26. Rifling-plate.—(1) Conceive the bore of a rifled-gun rolled out flat. Each groove will make a curve with an element of the bore. The form of the curve depends entirely on the design of rifling. In the case of rifling of uniform twist it would be a

straight line. Suppose that a new design of rifling is decided upon; the problem is to put this form of rifling in a gun.

(2) An accurate drawing is made showing the form that the curve would have were the bore rolled out flat. A cast-iron plate is then taken of a length somewhat greater than that of the bore to be rifled, one edge planed straight, and the other accurately cut to the form shown on the drawing. This plate, called a *rifling-plate,* is bolted horizontally to the edge of the rifling-machine and the necessary preparations made for transferring the curve to the *rifling-bar* (see Fig. 8).

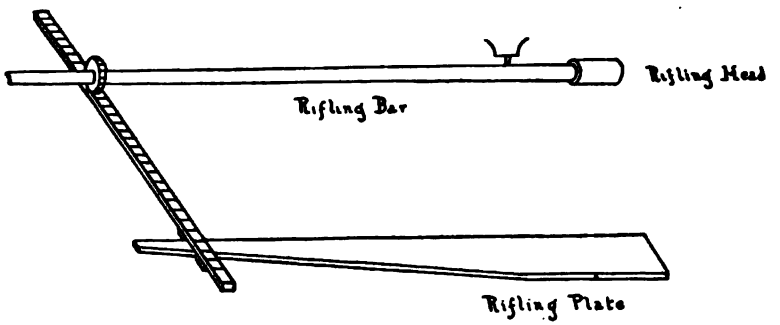


FIG. 8. ART. 26.

27. Rifling-bar.—(1) The *rifling-bar* is a long steel cylinder of a diameter somewhat smaller than that of the bore to be rifled. The curve of rifling is transferred from the *rifling-plate* to the *rifling-bar,* as is shown in the sketch. The bar, carrying with it the rack and gear wheels, is pushed forward against a cutting tool. The bar has a motion of translation and is at the same time given a motion of rotation by the action of the rack following the curve of the *rifling-plate.* The result is that a spiral slot is cut in the *rifling-bar* which, should the *rifling-bar* be rolled out flat, would be of the same form as the designed curve on the *rifling-plate.* Several cuts are required and the slot is finally made about .5 of an inch wide and .5 of an inch deep. This is called the primary slot. We are now finished with the *rifling-plate* and it is stowed away.

(2) One *rifling-bar* can be used for several designs of rifling, but a different bar is generally necessary for each caliber of gun. Each slot is plainly marked so as to avoid confusion.

28 Rifling-head.—On the end of the *rifling-bar* is secured the *rifling-head.* This head is a hollow steel cylinder, slightly smaller in diameter than the bore of the gun, and containing four cutters at right angles. The sockets for these cutters are dove-tailed into a tapered wedge which has a motion parallel to the axis of the bore. By moving this wedge the cutters may be set in or out radially by the desired amount. The mechanical principle is similar to that of the star-gauge. The cutters may also be set in or out independently.

29. Operation of rifling.—(1) All rifling is done from the muzzle-end. The gun is placed securely in steady-rests, in accurate prolongation of the axis of the rifling-bar. The rifling-bar is supported by steady-rests in the rifling-machine which somewhat resembles the ordinary lathe. The forward steady-rest of the rifling-bar contains a pin which engages in the slot cut in the bar. As the bar is fed into the gun the slot, guided by the pin. causes the bar to revolve and spiral grooves are cut in the bore of the desired form. The cutters are of the same section as the grooves to be cut. A very small cut, about .002 of an inch, is taken on each travel of the bar, so that 15 to 30 cuts are required to get the necessary depth for four grooves. The workman is provided with the necessary gauges and steel points and the cutters are set out after each cut. When four grooves are finished either the rifling-head or the gun is turned the necessary amount, and four more grooves are finished; and so on, until the gun is completely rifled. The cutters are well lubricated in oil.

(2) Guns with grooves of plain section have the same width of groove throughout and require but one slot on the rifling-bar. Guns with hooked-section grooves have the grooves about .07 of an inch wider at the breech-end than at the muzzle. In order to effect this an entirely separate slot is needed in the bar. After the *primary* slot has been cut on the rifling-bar, one end of the rifling-plate is set out the required amount, and a *secondary* slot is cut. This slot is of almost the same form as the *primary* slot but varies just enough to allow the extra width of groove to be

made at the breech-end. All the primary rifling is done first and then the guide-pin is shifted to the secondary slot and the grooves finished.

30. Lapping the bore.—(1) The bore of the gun is "lapped out" to remove the burrs caused by the cutters of the rifling-head. The gun is placed on skids of a convenient height. Two kinds of tools are used, one for the grooves and one for the lands. The grooves are lapped first.

(2) The lapping tool for the grooves consists of a head or spider having four arms, each bearing a copper lap, fitting in the grooves. This tool is entered in the muzzle of the gun, drawn through the bore to the origin of rifling, and then back again to the muzzle, the motion being reversed by suitable gearing. The gun is well slushed with emery-powder and oil, and the lap is drawn back and forth until the surfaces and edges of the grooves are smooth. The tool is then shifted and four more grooves lapped out.

(3) The lands are lapped by using a half-cylinder of lead, the gun itself being turned so as to cover the whole surface. Finally a burlap cylinder is used to clean and polish the bore. Care is taken not to injure the compression slope or to lap unevenly.

(4) The bore is now bore-searched and star-gauged both in the grooves and on the lands. It is found that the lapping may increase the diameter of the bore a few thousandths of an inch, and if the bore is originally too small, it may be slightly increased by lapping.

31. Fitting breech mechanism.—The necessary holes for fitting the breech mechanism are drilled, the hinge-plate or hinge-bolt put in place, and the breechblock fitted. Previously to fitting the breechblock, it is fitted in a dummy gun so that when actual fitting takes place the work will not be so difficult. There is always considerable hand-work in fitting every breech mechanism. When the fitting is complete the block is marked with the number of the gun.

32. Putting on yoke.—The yoke, of forged steel, is put on in a variety of ways. In most guns there is a shoulder against which the yoke abuts. In some small guns the yokes are shrunk on, but in the large guns the yokes are put on without shrinkage. Usually a shoulder prevents movement forward, and steel rings

or a screwed collar keep the yoke from going to the rear. The yoke is now considered part of the gun.

33. Balancing for center-of-gravity.—The gun and breech mechanism, with a projectile and charge, is balanced on knife-edges to find the center-of-gravity. This is done for only one gun of a type. The center-of-gravity of each gun is previously computed, in addition, for convenience in designing.

34. Weighing.—The gun and breech mechanism complete is weighed and the weight plainly marked on the breech-end of the gun. It is found that each gun of a type has a slightly different weight. The weight of the breech mechanism is also marked on its rear face for convenience, but this weight is included in the weight of the gun.

35. Final inspection.—The gun is now finally inspected. All outside dimensions are verified, breech mechanism set up and worked, and all hand-work thoroughly examined.

36. Marking.—There is a standard marking for guns of all calibers, showing the mark, number, and weight of the gun, and the initials of the officers concerned in its manufacture. The initials of the officer in charge of the proving grounds are added when the gun has been proved.

37. To fit to slide and prove.—(1) The gun is now fitted to its slide. The trunnions of the slide are placed on knife-edges and the position of the gun in the slide is adjusted so that the loaded gun and slide will just balance. The sights are on the slide, cylinders filled, firing connections in place, and, so far as possible, the gun is in exact service condition.

(2) The gun is then sent, either with or without mount, to Indian Head for proof. Five shots are fired and the gun is returned to the gun factory.

38. Lap, bore-search, and star-gauge.—The gun is again lapped and cleaned, and then bore-searched for any defects that may have developed on proof. It is again star-gauged in the powder chamber and on the lands to ascertain if the inner diameters have changed during proof. It is found that the bore of the gun has hardened considerably from the effects of firing, and the lapping is more difficult than before proof.

39. Final finishing.—The hoops sometimes jump slightly on

proof, due to a readjustment of the strains set up in assembling. The rear face of the gun is filed off smooth, if necessary, and the breech mechanism is overhauled to see that it works freely. The gun is now coated outside with heavy oil and inside with white lead and tallow, and sent to the storehouse ready for shipment.

4. Recent Designs.

40. Tendency in gun design.—(1) Formerly the steel makers could not provide *long* hoops of the necessary quality and strength, and designers were forced to use several short hoops. Long hoops can now be furnished of the required quality and strength, and fewer parts are being used in modern guns.

(2) Owing to the fact that smokeless powder causes a considerable pressure in the chase of guns, all large guns are being hooped to the extreme muzzle to provide the necessary strength along the chase. The muzzles of all guns are made bell-shaped to give additional strength.

(3) The increased power gained by lengthening the bore of guns has been recognized, and all our latest designs show an increase in the length of gun (see Plates II, III, and IV).

41. The Mark VI, 50-caliber, 6-inch guns (Plate III) comprise Nos. 204 to 253, inclusive, and are for the battleships Maine, Ohio, and Missouri. These guns are all loaded in the ordinary manner, and fitted with Vickers breech mechanism known as Mark VI. They are mounted on the Mark X pedestal mounts.

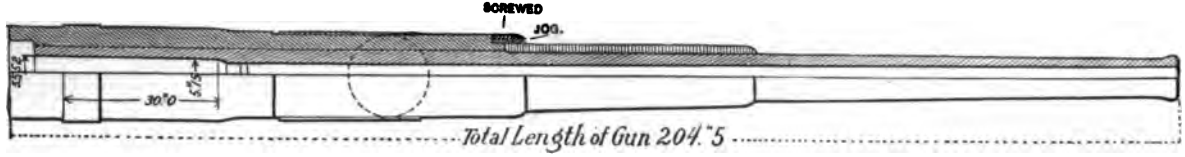
(1) *The gun* is composed of a tube, jacket, chase hoop *E*, chase-locking hoop *D*, jacket hoops *B* and *A*, and a short jacket-locking hoop *C*, merely screwed on. The tube is 293.74 inches long, and the jacket (total length 131 inches) is shrunk over its rear end for a length of 124.74 inches. The screw-box in assembling being of smaller diameter than the tube, brings up on the rear face of the latter. The screw-box is afterwards bored out to a larger diameter than the tube to receive the screw-box collar. A locking shoulder, 3 inches long, is left on the jacket near the front end, forward of which to the end (18 inches) the jacket is turned down to a diameter of 15½ inches, leaving a large front shoulder and jog. The *E* (chase) hoop, 90½ inches long, is shrunk over the

tube forward of and abutting against the jacket, and also abutting against a small radius at the same point on the tube, which is turned cylindrical under *E*. The *D* or chase-locking hoop, 39 inches long, is shrunk on over the rear end of *E*, the turned-down end of the jacket abutting against the shoulder on *E*; also a hook, 2 inches long, brings up on a shoulder left on the *E* hoop, thus locking the chase hoop to the jacket. The jacket hoop *B* abuts against and covers the shoulder on jacket and abuts against the rear face of *D*. The *A* hoop covers the jacket to the breech face. That part of the *B* hoop's outer surface over the jacket shoulder for a length of 3 inches has turned on it a right-hand thread, and a short locking hoop *C* (7 inches long) is then screwed on. A hook brings up on a shoulder left on *D*, thus locking together the whole system. Over the gun's center of gravity for a length of 44 inches the gun is cylindrical on a diameter of 22.30 inches. It is planed off to a diameter of 21.75 inches, leaving a longitudinal key 3 inches wide at the top and bottom to prevent the gun turning within the slide. The maximum diameter of the gun body is 24 inches, extending from 7 inches to 47.5 inches forward of the breech except for the yoke shoulder (2½ inches wide, diameter 24½ inches) which is 24 inches forward of the breech face. The muzzle of the gun is bell-shaped, diameter of bell 10½ inches, diameter of neck 9 inches. The gun is otherwise shaped as shown. Total weight of gun including breech mechanism is about 18,900 pounds.

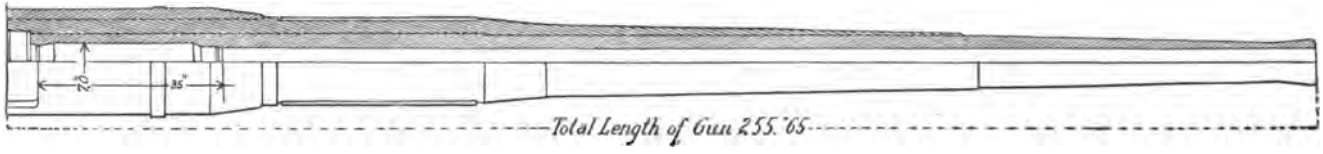
(2) *A hinge plate* to carry the breech mechanism is bolted to the right side of the breech in a slot cut in the circumference of the *A* hoop and is held by four radial screws, such that the center of the hinge-pin hole lies without the gun.

(3) *The screw-box* is formed in the collar. The collar, 6.258 inches long and 12.8 inches diameter, is screwed into the recess in the jacket to the rear of chamber. The screw-box is of the Welin or stepped-screw type, being planed out to form nine sections, a blank and two steps in three groups. The diameters of the blanks are 10.75 inches and threaded sections 10 inches and 9.25 inches. The threaded sections are separated by a space of ⅛ inch to facilitate manufacture. The threads are right-handed abutment threads, pitch 0.5 inch, depth 0.25 inch.

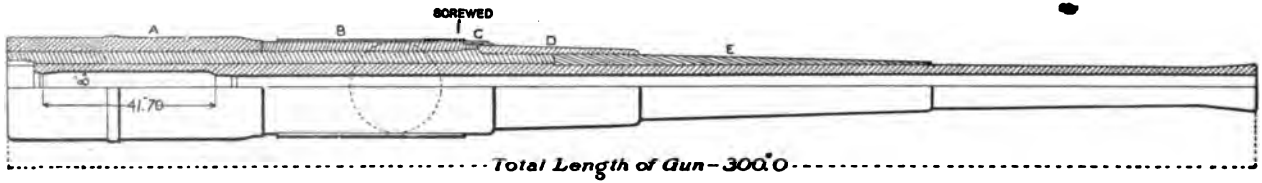
3-INCH RAPID FIRE GUN, MARK III.



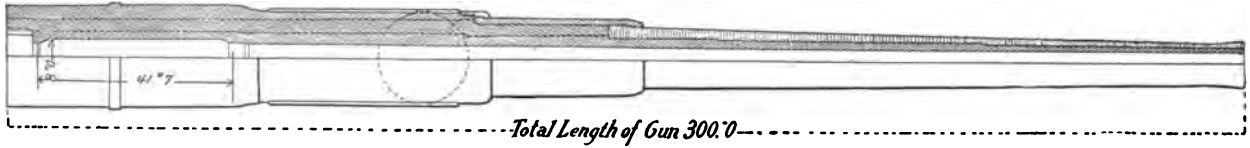
4-INCH RAPID-FIRE GUN, MARK VII.



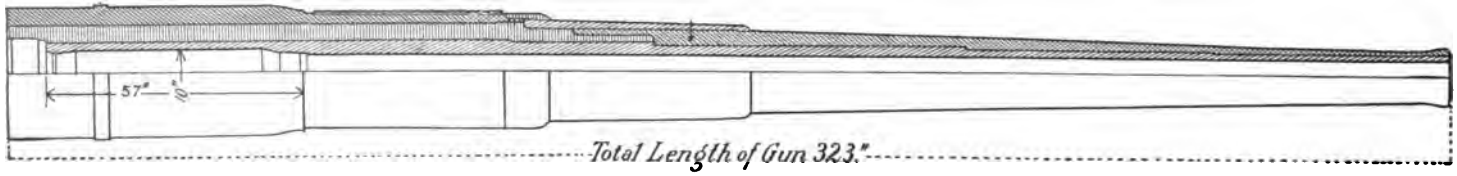
5-INCH BREECH-LOADING RIFLE, MARK V.



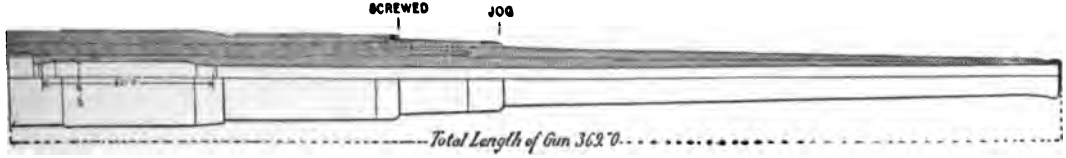
6-INCH BREECH-LOADING RIFLE, MARK VI.



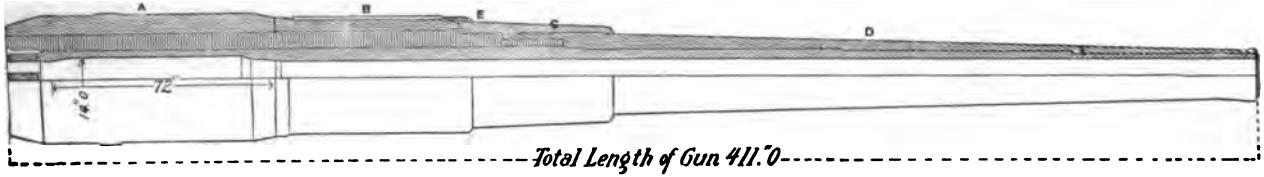
6-INCH BREECH-LOADING RIFLE, MARK VIII.



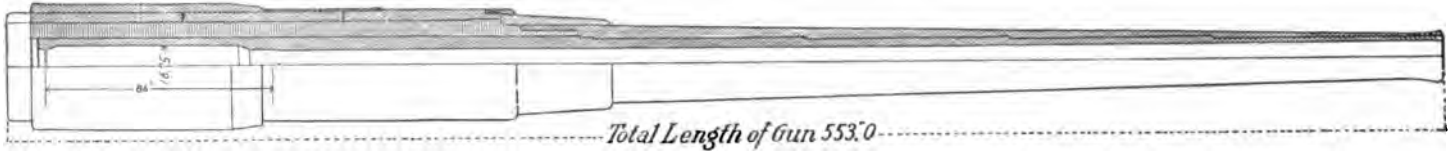
7-INCH BREECH-LOADING RIFLE, MARK II.



8-INCH GUN, MARK VI.



10-INCH GUN, MARK III.



12-INCH GUN, MARK V.

(4) *The chamber* has a total length of 48.416 inches from the rear face of the tube to the rifling at front end of compression slope. It is of the enlarged type, with restricted mouth and a double loading slope. The mouth consists of the gas-check seat 1.35 inches long, tapering from a diameter of 7⅞ inches at the rear face of the tube to 7¼ inches, and thence cylindrical for ½ inch. This is joined by a straight taper 4 inches long to the powder chamber, which has a diameter of 8 inches, the end of the taper being curved with an inside radius of 4 inches. The powder chamber is cylindrical for 34.7 inches to the first loading slope, which is a straight taper 4 inches long to a diameter of 6½ inches, the ends being rounded by inside and outside radii of 4 inches and 1 inch, respectively. Then comes the second loading slope (3.83 inches long) a straight taper to 6.14 inches diameter ending at the compression slope. This slope is composed of a taper (0.28 inches long) to a diameter of 6.10 inches; thence cylindrical for 0.556 inch to the second slope; then tapers (0.20 inch long) to 6 inches diameter formed by inside and outside radii of 0.21 inch to the rifling. The total length for powder charge is about 40½ inches.

(5) *The rifling* consists of 24 equal grooves, hooked section, 0.4847 inch wide at the rear end and decreasing to 0.4147 inch wide at the muzzle and 0.05 inch deep. It is a right-handed twist increasing from 0 at the origin to one turn in 25 calibers at the muzzle. The length of rifled bore is 245.526 inches.

42. Latest 6-inch gun.—The 6-inch, 50-caliber, Mark VIII gun is shown in Plate III. A comparison of this gun with the Mark VI, described in the previous paragraph, illustrates the tendency to strengthen the chase of new guns. It will be noted that the chase hoop in the Mark VIII gun extends from the forward end of the jacket to the muzzle; the exterior diameter at a distance of one foot from the muzzle is increased from 9 inches to 10 inches; the swell of the muzzle is longer, and the diameter at the top of the swell is increased from 10½ inches to 11 inches. In other respects the differences in these two marks are immaterial.

43. New 7-inch gun.—The 7-inch, 45-caliber, Mark II gun is shown in Plate III. It will be noted that, in the general features of its design, this gun is similar to the 6-inch Mark VIII. The parts and principal dimensions are shown in the figure.

44. Attention is invited to the simplicity of construction of the 5-inch, 50-caliber, Mark V gun (Plate II). The jacket and chase hoops are combined in one long part, shrunk on from the muzzle. The screw-box collar screws into the jacket abutting against the tube, and is of great importance in locking the two parts together.

45. The latest 8-inch, 10-inch, and 12-inch guns are shown in Plate IV. In all these guns we find a long chase hoop carried to the muzzle, with the same general method of construction and arrangement of locking hoops as for the 6-inch and 7-inch guns. In reducing the number of hoops in comparison with guns designed a few years ago, and in carrying the chase hoop from the jacket to the muzzle the girder strength is greatly increased to resist drooping in long guns. There is also more metal, and greater strength from the shrinkage of the chase hoop to resist the increased or sustained pressure along the bore, due to smokeless powder. The locking system, and the stiffness of the construction, gives great longitudinal strength, and foreshadows the next change in gun construction which will doubtless be the adoption of two tubes continuous from breech to muzzle.

In the 12-inch gun a D hoop is shrunk on over the rear jacket hoop, giving four thicknesses over the powder chamber.

46. Table of elements.—A table of elements of U. S. Naval guns of all calibers, which was correct to January, 1905, will be found at the end of this chapter.

BALLISTIC ELEMENTS OF U. S. NAVAL GUNS.

	Guns.	Cal.	Mark.	Length in inches.	Capacity of powder chamber in cu. in.	Travel of projectile. In.	Weight of projectile in pounds.		Initial velocity. F. S.	Pressure in tons.		Weight of charge.		Weight ballistic. Sample.	Weight ignition charge.
							Com.	A. P.		Max.	Min.	Max.	Desired.		
1 Pdr.	1 Pdr. (H. Light Short)	20	I	33.15	4.69	25.90	1.+	....	1450	8	....	40 gms.	35 gms.	10 lbs.	....
	1 Pdr. (" " Long)	35	I Mod.	....	4.69	....	1.+	....	1450	8	....	40 "	35 "	10 "	....
	1 Pdr. (D. S. Light)	..	II Exp.	....	.....	....	1.+	....	....	....	....	....	....	....	....
	1 Pdr. (" " Heavy)	40	II	61.08	7.43	53.36	1.+	....	2000	11	10	....	....	10 lbs.	....
	1 Pdr. (" " ")	40	II Mod.	....	7.43	....	1.+	...	2000	11	10	....	....	10 "	....
	1 Pdr. (H. Heavy)	40	III	62.00	7.43	53.00	1.+	....	2000	11	10	....	....	10 "	....
	1 Pdr. (D. S. Heavy)	50	IV	75.98	7.43	67.93	1.+	....	2000	11	10	....	....	10 "	....
	1 Pdr. (H. ")	40	V	62.37	7.43	53.07	1.+	....	2000	11	10	...	....	10 "	....
	1 Pdr. (M. N. Heavy Aut)	40	VI	89.50	7.43	57.07	1.+	....	2000	11	10	....	....	10 "	....
	1 Pdr. (" " Lt. Long Aut)	30	VII	69.35	4.69	40.42	1.+	....	1450	8	....	40 gms.	35 gms.	10 "	....
	1 Pdr. (H. Semi-Aut.)	40	VIII	62.37	7.43	53.07	1.+	....	2000	11	10	....	....	10 "	....
	1 Pdr. (M. N. Light Short)	..	IX	....	.....	....	1.+	....	1450	8	....	40 gms.	35 gms.	10 "	....
	3 Pdr. (S. A.)	..	XI	....	.....	....	....	....	....	....	...	....	....	....	....
3 Pdr.	3 Pdr. (H.)	40	I	80.63	46.42	60.30	3.+	....	2200	15	....	400 gms.	360 gms.	20 lbs.	....
	3 Pdr. (H. French)	..	I Mod.	....	46.42	....	3.+	....	2200	15	....	400 "	360 "	20 "	....
	3 Pdr. (D. S.)	45	II	87.95	46.42	69.49	3.+	....	2200	15	....	400 "	360 "	20 "	....
	3 Pdr. (M. N.)	..	V	....	46.42	....	3.+	....	2200	15	....	400 "	360 "	20 "	....
	3 Pdr. (H. Semi-Aut.)	50	IV	99.05	46.42	78.74	3.+	....	2200	15	...	400 "	360 "	20 "	....
	3 Pdr. (D. S.)	..	III	....	46.42	....	3.+	....	2200	15	....	400 "	360 "	20 "	....
	3 Pdr. (M. N. Semi-Aut.)	..	VI	....	46.42	....	3.+	....	2200	15	....	400 "	360 "	20 "	....
	3 Pdr. (H. Armstrong)	.	VIII	....	46.42	....	3.+	....	2200	15	....	400 "	360 "	20 "	....
	3 Pdr. (M. N.)	..	VII	....	.....	....	....	....	....	....	...	....	....	....	....
	3 Pdr. (M. N. R. F.)	..	IX	....	.....	....	....	....	....	....	....	....	....	....	....
	3 Pdr. (Semi-Aut. H.)	..	X	....	.....	....	....	....	....	....	....	....	....	....	...

BALLISTIC ELEMENTS OF U. S. NAVAL GUNS.—CONTINUED.

Guns.		Cal.	Mark.	Length in inches.	Capacity of powder chamber in cu. in.	Travel of projectile. In.	Weight of projectile in pounds.		Initial velocity. F. S.	Pressure in tons.		Weight of charge.		Weight ballistic. Sample.	Weight ignition charge.
							Com.	A. P.		Max.	Min.	Max.	Desired.		
6 Pdr.	6 Pdr. (H.)	40	I & II	97.63	50.52	79.17	6. +	....	2240	15	....	600 gms.	550 gms.	20 lbs.	....
	6 Pdr. (") Long	45	III	108.86	50.52	90.39	6. +	....	2240	15	....	600 "	550 "	20 "	....
	6 Pdr. (D. S. Field)	30	IV	72.00	32.99	59.87	6. +	....	....	....	....	....	....	....	....
	6 Pdr. (D. S. Field)	30	IV Mod.	72.00	32.99	59.87	6. +	....	....	....	....	....	....	....	....
	6 Pdr. (Field. Lynch Mec.)	30	V	72.00	32.99	59.87	6. +	....	....	....	....	..	....	....	....
	6 Pdr. (D. S.)	45	VI	107.33	50.52	90.39	6. +	....	2240	15	....	600 gms.	550 gms.	20 lbs.	....
	6 Pdr. (H.)	45	VII	108.86	50.52	90.39	6. +	....	2240	15	....	600 "	550 "	20 "	....
	6 Pdr. (D. S.)	50	VIII	118.55	50.52	101.60	6. +	....	2240	15	....	600 "	550 "	20 "	....
	6 Pdr. (M. N. Semi-Aut.)	45	IX	103.25	50.52	84.25	6. +	....	2240	15	....	600 "	550 "	20 "	....
	6 Pdr. (Nord.)	..	X	...	.....	....	....	....	....	....	....	....	....	....	....
	6 Pdr. (D. Seab'y. S. A.)	50	XI	120.00	50.52	101.46	6. +	....	2240	15	...	600 gms.	550 gms.	20 lbs.	....
	6 Pdr. (H. Armstrong.)	..	XII	....	.....	....	....	....	....	....	....	....	....	....	....
	6 Pdr. (S. A. R. F.)	..	IX Mod.	....	.....	....	....	....	....	....	....	....	....	....	....
3 in. F. G.	3-Inch	25	I & I Mod.	69.60	32.51	59.60	13.2	Shrap.	1150	11	....	250 gms.	230 gms.	20 lbs.	....
3 in. 50 Cal.	3-Inch	50	II	153.80	219.61	128.32	13	13	2700	16	15	....	....	100 "	25 gms.
"	3-Inch	50	III	154.30	219.61	127.92	13	13	2700	16	15	....	....	100 "	25 "
4 in. 40 Cal.	4-Inch	40	I Con.	163.75	331.22	131.61	33	33	2000	15	14	....	....	100 "	40 "
	4-Inch	40	I Con.	159.75	331.22	128.00	33	33	2000	15	14	....	....	100 "	....
	4-Inch	40	II	164.00	331.22	132.00	33	33	2000	15	14	....	....	100 "	....
	4-Inch	40	III	164.00	331.22	134.50	33	33	2000	15	14	....	....	100 "	....
	4-Inch	40	IV	164.00	331.22	134.50	33	33	2000	15	14	....	....	100 "	....
	4-Inch	40	V	164.00	331.22	134.50	33	33	2000	15	14	....	....	100 "	....
	4-Inch	40	VI	164.00	331.22	134.50	33	33	2000	15	14	....	....	100 "	....
4 in. 50 Cal.	4-Inch	50	VII	204.50	652.25	168.27	33	33	2800	16.5	15.5	....	....	100 "	60 gms.

BALLISTIC ELEMENTS OF U. S. NAVAL GUNS.—CONTINUED.

Guns.	Cal.	Mark.	Length in inches.	Capacity of powder chamber in cu. in.	Travel of projectile. In.	Weight of projectile in pounds.		Initial velocity. F. S.	Pressure in tons.		Weight of charge.		Weight ballistic. Sample.	Weight ignition charge.
						Com.	A. P.		Max.	Min.	Max.	Desired.		
4.7 in. 4.7-Inch	45	I	....	.....	....	45	....	....	....	....	13.75 lbs.	13 lbs.	100	....
4.7-Inch	45	II	....	.....	....	45	....	....	....	..	13.75 "	13 "	100	....
4.7-Inch	50	III	23ð.20	480.61	205.30	45	....	2600	14.9	....	13.75 "	13 "	100	....
4.7-Inch	..	IV	....	.....	....	....	....	....	....	....	....	....	....	....
5 in. 40 5-Inch	30	I Con.	159.97	656.07	121.73	50	50	2200	15	14	....	....	200	60 gms.
5-Inch	40	II	206.00	656.07	167.76	50	50	2300	15	14	....	...	200	60 "
5-Inch	40	III	205.83	656.07	167.76	50	50	2300	15	14	....	....	200	60 "
5-Inch	40	IV	206.00	656.07	167.76	50	50	2300	15	14	....	...	200	60 "
5 in. 50 5-Inch	50	V	255.65	1200.00	215.67	60	60	2800	16.5	15.5	....	....	300	100 "
6 in. 40 6-Inch	30	I	189.70	1420.52	139.05	105	105	1950	15	14	....	....	300	100 "
6-Inch	30	II Con. A.	193.53	1317.89	142.93	105	105	1950	15	14	....	....	300	100 "
6-Inch	30	III	196.00	1311.04	149.66	105	105	1950	15	14	...	....	300	100 "
6-Inch	30	III Con. A.	196.00	1317.89	145.40	105	105	1950	15	14	....	....	300	100 "
6-Inch	30	III Con. B.	196.00	1317.89	145.40	105	105	1950	15	14	....	....	300	100 "
6-Inch	35	III Mod. 1	226.00	1311.04	179.66	105	105	2050	15	14	....	....	300	100 "
6-Inch	40	III Mod. 2	256.00	1311.04	209.66	105	105	2150	15	14	....	....	300	100 "
6-Inch	40	III Con. D.	256.00	1317.89	205.40	105	105	2150	15	14	....	....	300	100 "
6-Inch	40	IV Mod.	256.41	1317.89	205.81	105	105	2150	15	14	....	....	300	100 "
6-Inch	40	IV Mod.	256.10	1317.89	205.50	105	105	2150	15	14	....	....	300	100 "
6-Inch	40	VII	254.11	1317.89	205.81	105	105	2150	15	14	....	....	300	100 "
6 in. 50 6-Inch	50	V	309.25	1091.47	267.30	105	105	....	15 5	14.5	....	...	300	100 "
6-Inch	46	VI Expl	276.258	2101.02	223.78	105	105	2800	15 5	14 5		..	300	100 "
6-Inch	50	VI	300.00	2101.02	247.52	105	105	2800	16.5	15.5	...	...	300	100 "
6-Inch	50	VIII	300.00	2101.02	247.52	105	105	2800	16.5	15 5	44 lbs	40 lbs.	300	100 "
7 in. 45 7-Inch	45	I	315.00	3631.87	251.21	165	165	2700	17	16	....	...	400	3 Prisms.
7-Inch	45	II	323.00	3631.87	259.21	165	165	2700	17	16	. ..	....	400	3 "

BALLISTIC ELEMENTS OF U. S. NAVAL GUNS.—Continued.

Guns.		Cal.	Mark.	Length in inches.	Capacity of powder chamber in cu. in.	Travel of projectile. In.	Weight of projectile in pounds.		Initial velocity. F. S.	Pressure in tons.		Weight of charge.		Weight ballistic. Sample.	Weight ignition charge.
							Com.	A. P.		Max.	Min.	Max.	Desired.		
8 in. 35	8-Inch	30	I	257.09	3574.40	197.83	260	260	2000	15	14	....	....	400	7 Prisms.
	8-Inch	30	I	257.99	3661.01	196.83	260	260	2000	15	14	....	....	400	7 "
	8-Inch	30	I Con. A.	254.61	3517.24	196.84	260	260	2000	15	14	....	....	400	7 "
	8-Inch	30	II Con. A.	255.60	3517.24	197.83	260	260	2000	15	14	....	....	400	7 "
	8-Inch	30	III Expl.	261.00	3185.31	201.93	260	260	2000	15	14	....	....	400	7 "
	8-Inch	35	III	304.50	3185.31	245.43	260	260	2100	15	14	....	....	400	7 "
	8-Inch	35	III Mod. 1	304.50	3185.31	245.43	260	260	2100	15	14	....	....	400	7 "
	8-Inch	40	III Mod. 3	344.50	3185.31	285.43	260	260	2100	15	14	....	....	400	7 "
	8-Inch	35	IV	304 50	3185.31	245.43	260	260	2100	15	14	....	....	400	7 "
	8-Inch	35	IV Mod.	303.84	3185.31	244.77	260	260	2100	15	14	....	....	400	7 "
	8-Inch	35	IV Mod.	304.50	3185.31	245.43	260	260	2100	15	14	....	....	400	7 "
	8-Inch	35	IV Mod.	304.50	3165.07	245.43	260	260	2100	15	14	....	....	400	7 "
8 in 40	8-Inch	40	V	343.00	5250.22	272.65	260	260	2700	17	16	....	....	700	7 "
"	8-Inch	45	VI	369.00	5250.22	298.65	260	260	2750	17	16	....	....	....	....
10 in. 30	10-Inch	30	I	329.10	6906.29	249.91	510	510	2000	15	14	....	....	800	....
	10-Inch	34	I Mod.	365.60	6906.29	286.41	510	510	2000	15	14	....	....	800	....
	10-Inch	30	II	329.10	6860.09	249.91	510	510	2000	15	14	....	....	800	....
10 in. 40	10-Inch	40	III	411.00	10221.93	325.84	510	510	2600	17	16	....	....	1300	....
12 in. 35	12-Inch	35	I	441.00	12145.33	344.80	870	870	2100	15	14	....	....	1200	....
"	12-Inch	35	II	441.00	12145.33	344.12	870	870	2100	15	14	....	....	1200	....
12 in. 40	12-Inch	40	III	493.00	17623.60	388.80	870	870	2600	17	16	....	....	2200	....
"	12-Inch	40	III Mod.	493.00	17167.76	390.80	870	870	....	17	16	....	....	2200	....
13 in.	13-Inch	35	I	479.10	15289.85	373.19	1130	1130	2200	15	14	....	....	1600	....
"	13-Inch	35	II	479.10	15241.72	373.19	1130	1130	2200	15	14	....	....	1600	....

CHAPTER IV.

BREECH MECHANISMS.

1. Definition.—A breech mechanism, or fermeture, is a mechanical device for closing the rear end of the chamber or bore of a breech-loading gun. The term includes the breechblock or plug, all mechanism contained in or with it, and the necessary operating gear.

2. Requirements for a breech mechanism.—The following may be said to be the principal requirements for a successful breech mechanism:

(1) *Safety.*—To be safe: (a) The gas must be restrained from escaping to the rear; this sealing or obturation must be automatic, greater pressure insuring better obturation; (b) the breech of the gun must not be weakened by the fitting of the breech mechanism; (c) the parts must have ample strength to prevent any portion from being blown to the rear; (d) the danger of premature discharge must be minimized; (e) the breechblock must be securely locked to prevent *deculassment,* or opening on firing.

(2) *Ease and rapidity of working.*—Otherwise, rapid and continuous fire cannot be maintained. Hence this would include facility in loading and certainty of extraction for rapid-fire guns.

(3) *Not easily put out of order.*—In other words, it must be able to meet service conditions and hard usage. Parts should have a reserve of strength. All the mechanisms should be so designed as to be protected by the gun itself.

(4) *Ease of repair.*—Parts most exposed to wear should be so designed as to permit of being replaced. This will also include accessibility to parts, so that breakage of a part will not disable a mechanism for a long time.

(5) *Interchangeability.*—Not only should individual parts be made interchangeable by accurate workmanship, but the whole

mechanism should be capable of being mounted on similar guns. This is to meet service conditions.

3. The breechblock or plug is the movable piece closing the breech of a gun, withdrawn for loading, and closed before firing. It is carried in "built-up" guns by the jacket, within a screw-box, mortise, or housing. The term applies to any shape of piece, or any system of closure.

4. In small arms and certain special guns the term breech "bolt" is often used instead of plug or block; and "breech action" is a better term in this case than "breech mechanism."

5. Breech piece is a term sometimes used (as in the Krupp system) for the heavy piece of metal at the breech of a gun, which contains the breechblock.

Systems of Breechblocks for United States Navy Guns.

6. There are seven (Plate I) principal systems of breechblocks used in the United States Navy for both service and foreign-built guns, viz.:

(1) The interrupted screw (Fig. 1).

(2) The sliding wedge (Fig. 2).

(3) The rotary block (Fig. 3).

(4) The combined rotary and sliding-block systems (Fig. 4).

(5) The conical spiral thread (Fig. 5), successful on trial but not generally adopted.

(6) The sliding-bolt and turn-bolt systems (Figs. 6, 7, and 8).

(7) Special fermetures.

7. The interrupted-screw system is, in general, used for all guns of and above 3 inches in caliber. Secondary rapid-fire guns use systems (2), (3), and (4). Military rifles, as well as certain automatic and machine guns, generally use the *sliding-bolt system.* "Special fermetures" will be referred to as described.

8. Special guns, such as automatic guns, machine guns, etc., more properly use "breech actions," in which the different steps in closing the breech and operating the entire mechanism are very intimately connected. The systems in these cases are defined by the names of the guns.

9. In the U. S. Navy the interrupted-screw system is found in nearly all of the main-battery guns; the sliding wedge in the

FIG. 1. INTERRUPTED SCREW.
ALL MAIN BATTERIES.
4" PLUG.

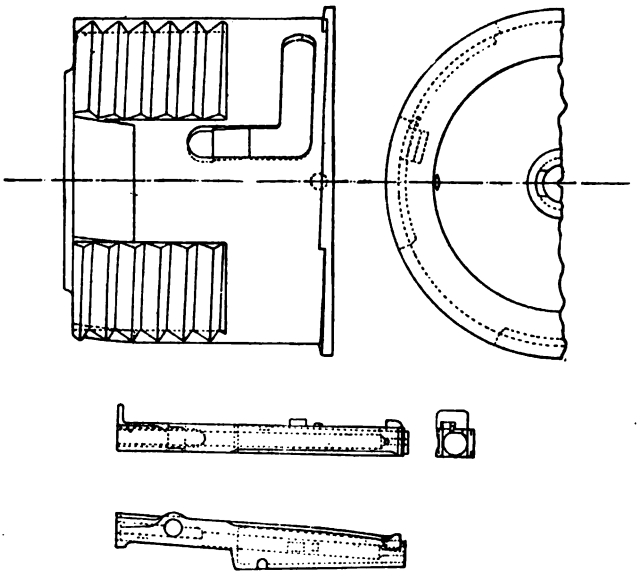


FIG. 2. SLIDING
NOTCHED

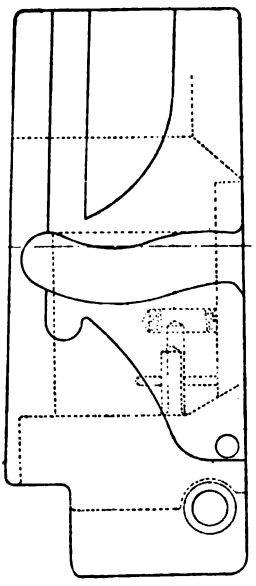
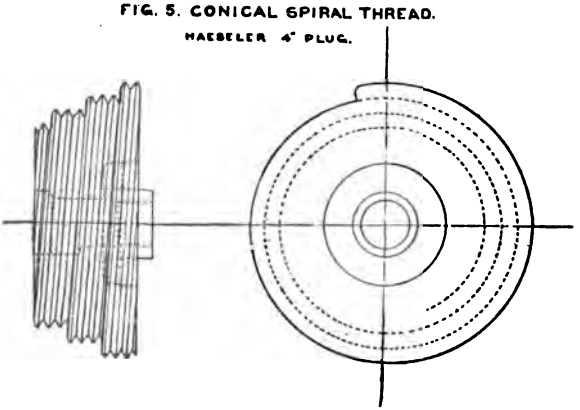


FIG. 6. SLIDING BOLT SYSTEM.
LEE STRAIGHT PULL.

FIG. 5. CONICAL SPIRAL THREAD.
MAESELER 4" PLUG.



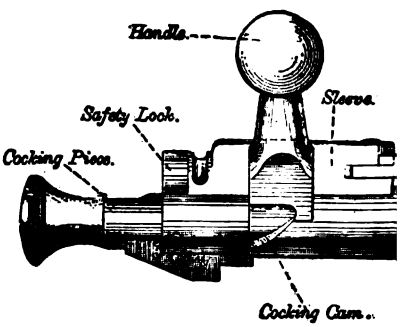


FIG.7. TURN BOLT

WEDGE.
6-PDR.

FIG. 3. ROTARY BLOCK.
BRIGGS-SCHROEDER 6-PDR.

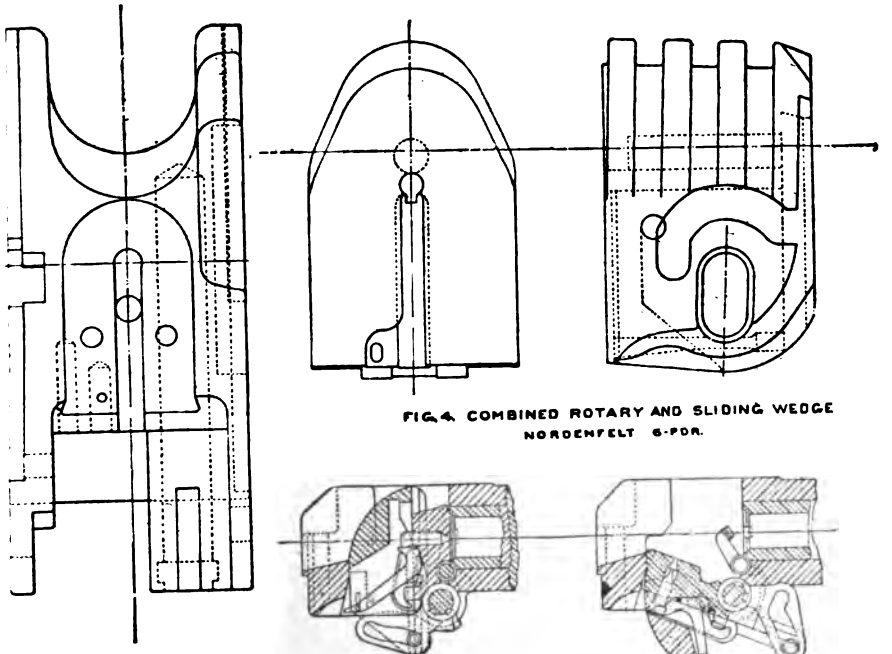


FIG. 4. COMBINED ROTARY AND SLIDING WEDGE
NORDENFELT 6-PDR.

T SYSTEM. U. S. MAGAZINE RIFLE.

FIG. 8. SLIDING BOLT SYSTEM.
GATLING, MARK II, .30 CAL.

REECHBLOCKS.

Hotchkiss 6-pounder, 3-pounder, and 1-pounder rapid-fire guns; Maxim 6-pounder and 3-pounder semi-automatic rapid-fire guns; the rotary block in the Driggs-Schroeder 6-pounder, 3-pounder, 1-pounder, and two 4-inch rapid-fire guns; the combined rotary and sliding-wedge system in the Nordenfelt 6-pounder and 3-pounder rapid-fire guns; and the conical spiral thread, experimentally in an 8-inch nickel-steel gun (previously one was made and tried in a 4-inch gun).

10. The interrupted-screw system, also called "slotted-screw," is divided into four classes (Plate II): (1) French interrupted screw (Fig. 1), (2) Elswick interrupted screw (Fig. 2), (3) Welin interrupted screw (Fig. 3), and (4) Maxim-Nordenfelt Mark M, or the Melstrom (Fig. 4).

NOTE.—In general, an interrupted-screw block means that the block, having been threaded, has two or more sections of the thread removed in the direction of the axis. Similar interruptions are made in the female thread of the screw-box in the gun, in order that the block may be entered or withdrawn in one motion, and only a portion of a turn given to lock or unlock it in the screw-box.

(1) *The French interrupted screw* (Fig. 1) is the ordinary system of fermeture and has been long in use. The breechblock, cylindrical in shape, has a male screw-thread cut on its circumference, the character of which varies according to particular designs. It is divided into a number of equal sections in the longitudinal direction (always divisible by two, usually six, eight, or twelve) and the threads of alternate sections are then slotted out. The female thread in the screw-box is similarly slotted. In closing the breech, the threaded sections of the block are brought opposite to the blank sections of the screw-box; the block is pushed in either by hand or by some sort of mechanism to the proper distance, and a fraction of a turn to the right or left is given to interlock the threaded sections. The amount of turn necessary depends upon the number of divisions; six divisions would require sixty degrees, eight divisions forty-five degrees, etc. The system is independent of the methods of operating the mechanism.

(2) *The Elswick interrupted screw* (Fig. 2) differs from the French, or ordinary, in that the forward part of the block is conical and the rear part cylindrical. The threaded sections of

the coned portion correspond longitudinally with the blank or planed sections of the cylindrical part. The advantages claimed for this arrangement are: (a) The working of the mechanism is facilitated, as the translation and swinging out or in can be accomplished in one motion; (b) the arrangement of the threaded sections distributes the strain over the entire circumference of the block; (c) the cone-shaped part distributes the engagement of the block throughout a large transverse section of the gun.

(3) *The Welin interrupted screw,* or "stepped-thread," system (Fig. 3) has the block divided circumferentially into twelve equal sections, of which three are blanks and the remaining nine threaded. Speaking of the block's threads which are the opposite of those of the screw-box, the blanks have the least diameters and the threaded sections are in three larger diameters, the blanks being between the highest and lowest of the threaded sections. The above describes the block for a 12-inch gun; for smaller guns there are only nine sections with three blanks and six threads in two steps. The blanks for these smaller mechanisms are cut away convexly and concavely, with the hinge-pin as a center, and the tops of some of the threads are filed off to permit the block to swing into the screw-box with no pronounced motion of translation.

(4) *The Maxim-Nordenfelt interrupted screw* (Fig. 4) has the following peculiarities: The block is slightly conical, larger end at the front, having a V-thread of slight pitch, and interrupted, not by planing down to the root of the thread, but by cutting off the metal of the block equally on opposite sides parallel to the axis, forming, more or less, a square cross-section. The screw-box is similarly shaped. The advantage claimed is that the block is less likely to be blown out with excessive pressures. There is no doubt that the method of interruption considerably weakens the block, and to make up in holding power the length of the block is a trifle longer than it would be with other systems.

11. The sliding-wedge system (Plate I, Fig. 2), exemplified in the Hotchkiss guns, has a rectangular wedge-shaped block (containing the firing mechanism) that slides up and down in a vertical mortise within the rectangular-shaped breech of the gun,

FIG. 1 FRENCH INTERRUPTED SCREW.

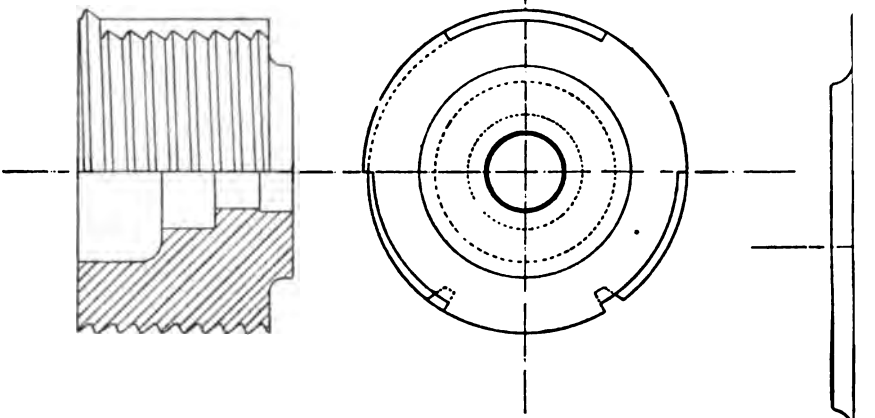
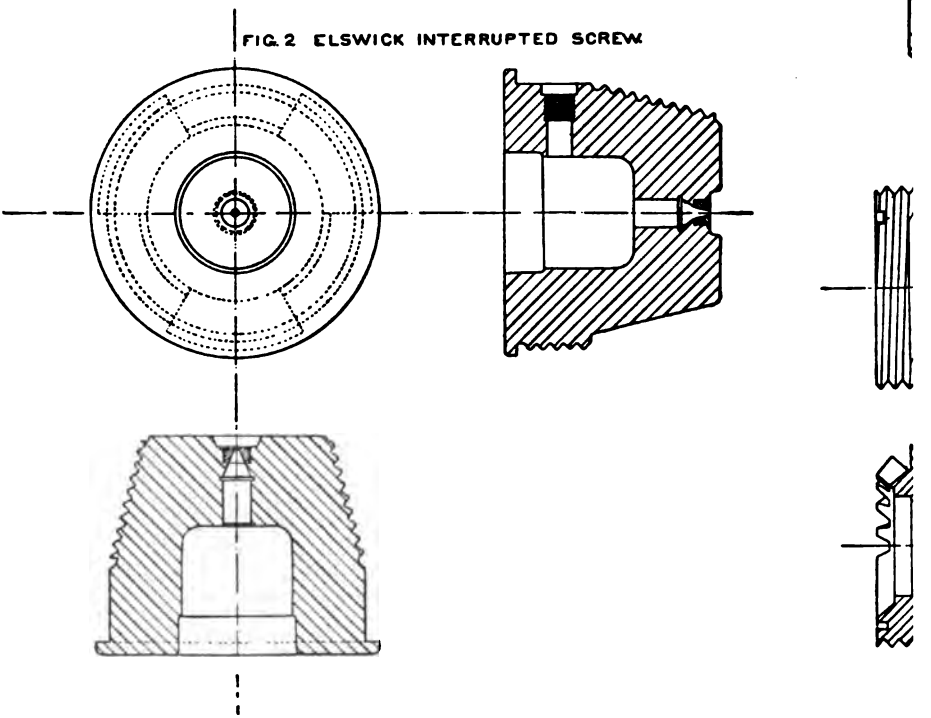
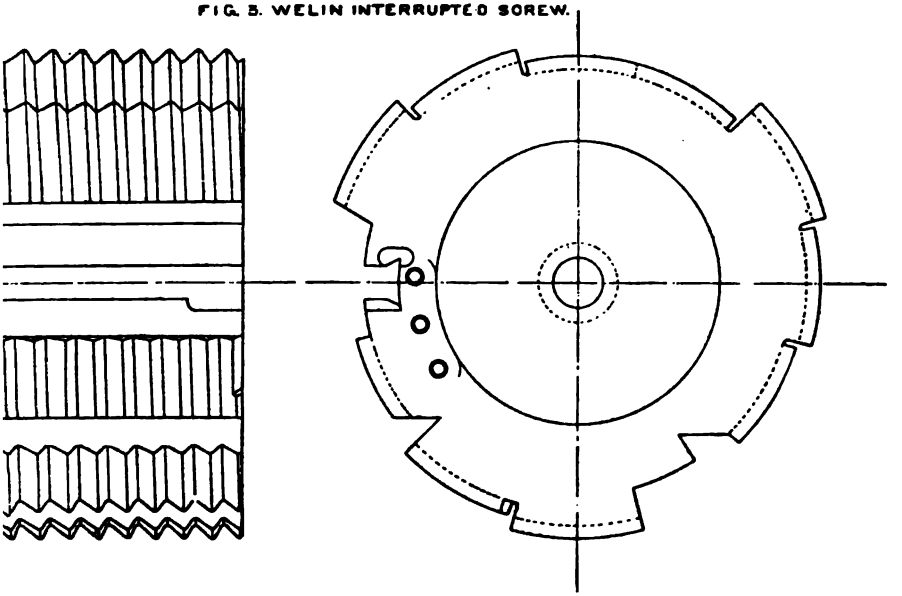


FIG. 2 ELSWICK INTERRUPTED SCREW.

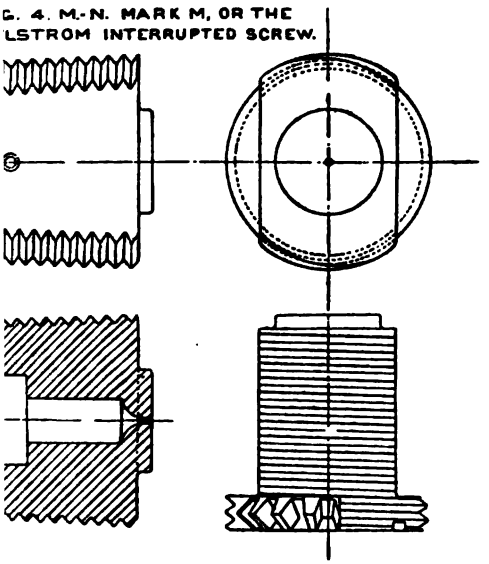


FOUR SYSTEMS OF INTE

FIG. 3. WELIN INTERRUPTED SCREW.



G. 4. M.-N. MARK M, OR THE
LSTROM INTERRUPTED SCREW.



UPTED-SCREW THREAD.

and is guided by vertical ribs. It is moved by means of a crank, journaled in the right cheek of the mortise; a stud on the other end of the crank moves in a cam groove in the side of the block. The wedge completely closes the mortise when up, and gives a sliding movement to the cartridge case in shoving it home.

12. Field-guns with this system usually have the block working transversely to the axis of the gun, instead of vertically.

13. The rotary-block system (Plate I, Fig. 3).—In this system, whatever the shape of the block, method of operation, or locking, the block rotates on an axis (generally transverse), to close or open the breech, the upper part of the block falling to the rear in opening. There may be some vertical movement for the locking or unlocking.

14. This system is exemplified in our service by the Driggs-Schroeder guns. It has a rectangular block with rounded top, working entirely within the breech-housing, and is locked by means of collars on the top of the block engaging in corresponding grooves in the housing. The grooves are inclined slightly to the front, so that the final movement in closing is upward and to the front, pushing the cartridge case home. The operation is through a cam within the block, moving against curved surfaces in the block's recess; this cam is moved by a transverse axis.

15. The combined rotary and sliding-wedge system (Plate I, Fig. 4) is represented in our service by the Nordenfelt 6-pounder and 3-pounder rapid-fire guns. The breechblock may be said to consist of two parts, the block and the wedge, the latter slides on the front face of the former in the locking or unlocking movement, while to cover or uncover the breech both rotate about a transverse axis, the top falling to the rear in opening.

16. The conical spiral-thread system (Plate I, Fig. 5) is represented by the Haeseler patent. Its inventor, Lieut. Haeseler, died soon after its completion. It was tried on one 4-inch and one 8-inch gun, but it has never been developed. A continuous triple thread is chased on the outside of the cone-shaped block; the thread is of comparatively steep pitch and has a varying diameter which gives the effect of a longitudinally-stepped block. The threads have less than one convolution on each step, however, and the different steps thus merge into each other.

17. Obviously, this system gives the lightest and shortest block and no motion of translation, as such, need be provided even in the largest sizes; it is also cheap to manufacture. However, the threads having a steep pitch and nearly a complete turn being necessary to lock and unlock, practical difficulties with the operating gear developed on the trials.

18. The sliding-bolt and turn-bolt systems (Plate I, Figs. 6, 7, and 8).—In these systems a more or less cylindrical piece, containing at least the firing-pin and spring or hammer, moves longitudinally in a "receiver" attached to the gun barrel, and may be worked either by hand, as for small-arm rifles, or by certain mechanism, as in the Colt-automatic gun. The bolt may have only a direct movement to the rear and front, giving the name "straight-pull," or may have a part attached which is turned for locking or unlocking, giving the name of "turn-bolt." These systems are exemplified in the Lee straight-pull rifle, the Krag-Jorgensen rifle, in the lock for each barrel of the Gatling gun, and in the Colt-automatic gun.

19. Special fermetures.—Under this head are grouped the various methods used in our service for closing the breech for secondary guns; exemplified in the vertical sliding carrier of the lock in the Maxim-automatic guns, and in the solid breechblocks of the revolving cannon.

Gas-Checks.

20. The gas-check is a device to prevent the escape of the powder gas to the rear around the breechblock or through the vent.

21. A vent-check was used with old guns to seal the vent against the pressure of the gas on firing; with modern guns, the primer is designed to seal the vent, being supported by the cartridge case and face of the breechblock in R. F. guns and by the firing-lock in the others.

22. Systems of gas-checks (Plate III).—There are four systems in use: (1) The cup gas-check; (2) the Broadwell ring; (3) the cartridge case; (4) the De Bange check. The last two are in use for modern guns, the cartridge case of course being used for rapid-firing guns.

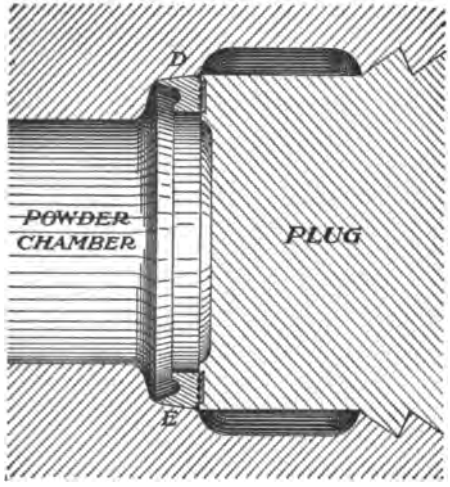


FIG. 1. D. E. Broadwell Ring.

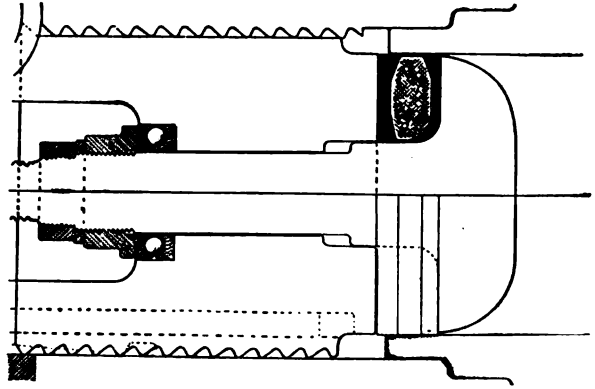


FIG. 2. The De Bange Gas-Check, with Disks.

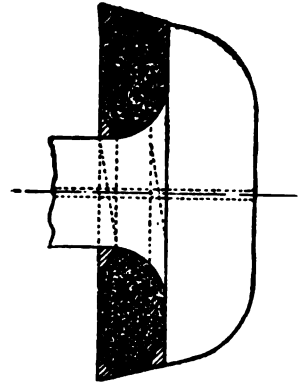


FIG. 3. The De Bange Gas-Check. Later form, showing split-rings.

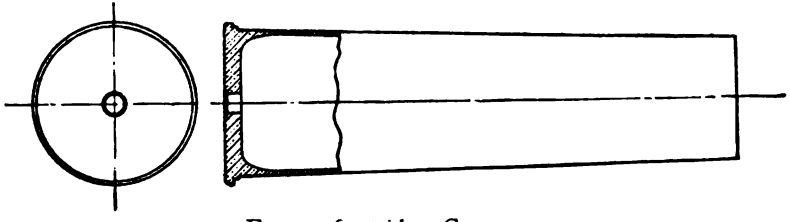


FIG. 4. Cartridge Case.

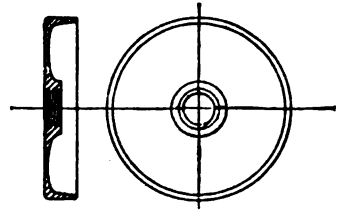


FIG. 5. Cup Gas-Check.

SYSTEMS OF GAS-CHECKS.

23. The cup gas-check (Plate III, Fig. 5) was fitted to the old howitzers. Though practically obsolete, it is mentioned in this connection because of the possibility that the great heat, pressure, and other conditions may in the future force a return to some form of metallic gas-check.

24. The Broadwell ring is the invention of Broadwell, an American, and has been largely used abroad by Krupp. It consists of a ring made of copper, recessed on the forward side. The flange fits and is retained in a correspondingly shaped recess in the gun at the front end of the screw-box. The flange extends a slight distance forward to give a good bearing surface in the recess. The rear face is perpendicular to the axis of the gun and has three shallow grooves to collect any residuum; it extends from 0.01 inch to 0.02 inch to the rear of the recess wall. The diameter of the inner flange is less than that of the chamber, to avoid displacement in sponging. On closing the breech, the face of the block, or a face-plate thereon, bears tightly on the rear face of the ring, making the joint with the gun and also the bearing with the block gastight. On firing the gun, the powder gas expands the flanges and sets the ring back hard against the block.

25. This check, in our service, is used in the old 3-inch breech-loading field-gun or howitzer. It is being experimented with, however, to determine whether the system, or some modification of it, may not be applicable to high-power guns. These experiments are the result of several failures of the De Bange check in recent guns using smokeless powder. It is possible that some combination of the Broadwell-ring principle with the pad of the De Bange check may be adopted which will prevent the injury of the pad in the case of abnormal powder pressure, and protect it from the intense heat of modern powders.

26. The cartridge case as a gas-check (Plate III, Fig. 4).— The metallic cartridge case used in rapid-firing guns forms a perfect gas-check. The heat and pressure of the powder gas on firing expands the mouth of the case against the powder chamber and restrains the gas from escaping to the rear. When the projectile is loaded in the case, the powder gas, being confined, will swell the case before the projectile leaves it. But where the ammunition is "separate," a mouth cup closes the case and

slightly confines the gas at first; this cup also serves to contain the charge and protects it from moisture,—it is blown out on firing. The mouth of the case should fit neatly in the chamber, when pushed home, otherwise there may be a slight leak at first. The effectiveness of cartridge cases as gas-checks, and the fact that they seldom stick, tends to show that some form of metallic gas-check for B. L. guns may be forthcoming.

27. The De Bange gas-check, or "pad obturator," is the type used in the United States Navy for all modern guns that are not *rapid-fire.* It is the invention of Colonel De Bange, of the French Army, and is now used in many special forms by practically all countries. The De Bange system of breech mechanism, considered by the French as the original interrupted-screw system, does not take its name from the gas-check.

28. The device consists of a mushroom-headed piece of steel with a stem which passes through an axial hole in the breechblock. Between the rear face of the mushroom head and the face of the block, surrounding the stem, are two steel disks or rings inclosing an obturator pad of asbestos and tallow within a suitably shaped canvas cover. Nuts screwed on the rear part of the stem, within the recess of the block, bind the parts together.

29. *The pad and mushroom* project beyond the screw-box into the chamber, the front disk and pad bearing on a smooth-sloped surface of the gun chamber, called the *gas-check seat or slope.*

30. *The action is as follows:* On firing the gun, the powder gas, acting on the front face of the mushroom, forces it back, compressing the pad between the disks or rings against the breechblock. This causes the pad and the front disk or ring to expand radially and equally all around against the gas-check slope, sealing all escape of gas to the rear. This check is effective in large as well as in small guns, though it took many years to prove it practically. It is commonly supposed that the pad alone checks the escape of gas. This is erroneous. The front ring assists materially in checking the gas, the pad acting as a cushion, or buffer, to prevent the ring from getting a permanent set which might result from the compression of the ring against a steel surface.

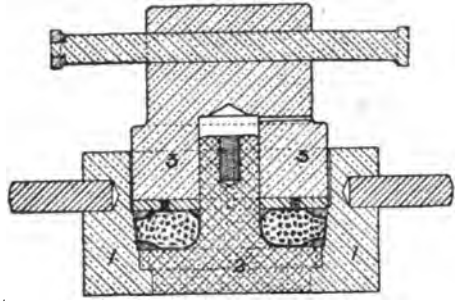
31. *The advantages* of this type are durability, certainty of action, easy adjustment, and ease with which replaced. Some pads have stood a thousand rounds; all should stand two hundred.

32. *The canvas* on the edges of the pad wears from the working of the mechanism but the cover can be replaced; it is better to fit an entire new cover than to patch an old one.

33. Details of manufacture (Plate IV).—The obturator cake is composed of 65 parts of asbestos and 35 parts of tallow; the covering is made of linen canvas. The asbestos is selected and finely pulverized; the tallow is tried from kidneys and particular care is taken to get it pure. The proper proportions of asbestos and tallow having been weighed out, the latter is melted and the asbestos mixed in with a wooden spatula; the cake is then allowed to cool before moulding.

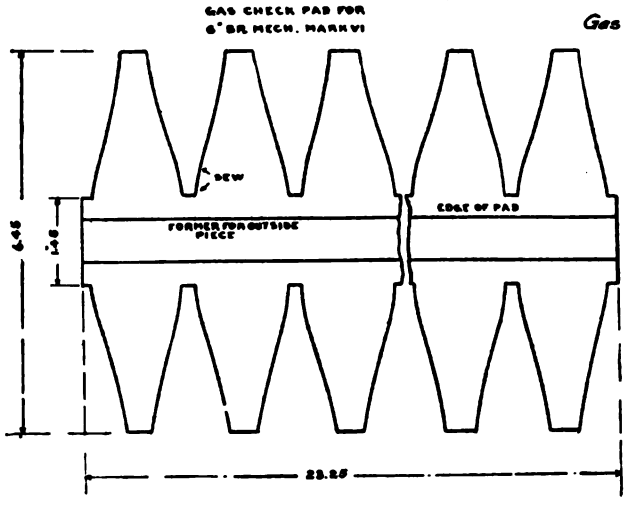
34. *The moulding apparatus* consists of the mould (1), the former (2), and the follower (3); the diameter is that of the finished pad plus 0.01 inch clearance. The upper surface of the former, with its flange, exactly reproduces the mushroom, stem, and front gas-check ring; the follower is of the same shape as the face of the breechblock with the rear split-ring or disk. In moulding a cake, a predetermined weight of the mixture is put into the mould and the follower lowered down over it; the cake is then subjected to a pressure of from 50 to 75 tons for about half an hour. The cover is made in two parts, as in the figure, very accurately cut and fitted to a wooden model representing the cake. The newly formed cake is taken from the mould, the ends of both parts of the cover are sewed together and the parts fitted to the cake. Then the points of the inner portion are hauled back over those of the longer outer part and the whole lightly tacked together; the pad is returned to the mould and subjected to a pressure about double that given in the first instance,—the amount given is the total pressure on the follower. The pad, having been removed, is then finish-sewn, with a blunt-pointed bent needle. It is then pressed again, with about the original pressure, after which the pad is complete and ready for service.

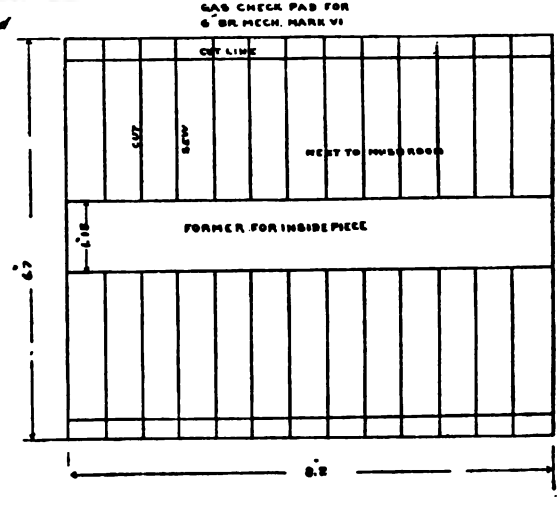
35. *The rings* are made of special steel; they are cut through radially, at an angle of about thirty degrees, and the ends soldered



Gas check pad mould

1- Mould
2- Former.
3- Follower.





MOULD AND FORMERS FOR GAS-CHECK PAD.

to hold them together while finish-machining. After being suitably shaped, the rings are hardened and finely tempered; the edges and rims are then very carefully ground to the exact dimensions, after which the soldered joint is broken and the ring is ready for service. All the early gas-checks had solid disks in lieu of these split-rings; then a rear disk was used with a front split-ring but was finally replaced by a split-ring. A third disk is generally used around the mushroom stem, against the face of the breechblock for centering and for protecting the pad from being cut.

36. *The mushroom* is also made of special steel; the shape is shown in the various mechanisms,—its diameter is such as to give it a neat but easy fit in the rear end of the chamber. The mushroom-stem extends to the rear through the block and is held by two heavy nuts, as shown in the plates, of which one acts as a jam nut. For the larger calibers, a frictionless washer is interposed between the nuts and the breechblock because the block must revolve around the mushroom while unlocking; this washer is omitted in the smaller calibers, where the necessary tension is given by a spiral spring. The *vent* extends along the axis of the stem; its rear part is enlarged to form the primer seat. On the end of the stem is cut a thread, or suitable collars, for the attachment of the firing-lock.

37. Adjustment of the De Bange gas-check.—The object in adjusting, *i. e.*, properly setting up the nuts of the mushroom-stem, is to give sufficient compression to the pad and rings to stop the first rush of gas and, at the same time, to keep the check from sticking in opening or closing.

38. When solid disks were used, great care was essential to give a clearance that would prevent this sticking, which is most likely to occur after firing. When this could be done, the disks gave good results. However, the split-rings expand more freely, giving better assistance to the pad and are not so likely to cut its cover. The only drawback is that, when expanded, they are not quite circular.

39. If the mushroom-nuts are so set up that the gas-check is felt to bear on its seat, causing slightly added resistance to the

operating gear, at the end of the locking motion, the adjustment will be about right. If the check is too loose, it is not probable that any gas will really get past it but it *will* get more freely to the pad, resulting in burning its cover or cutting it on the sharp edge of the rings and permitting the contents to escape. When in doubt as to the bearing of the gas-check, put longitudinal chalk marks on its seat and close the breech. If the check is tight enough, these marks should appear all around the pad and front ring; the rear ring or disk should not quite touch.

Systems of Operating Breech Mechanisms.

40. It may be said that there are two general systems: (1) *Ordinary,* (2) *Quick-acting.* Each of these is subdivided into certain types. These types often give the name of the gun, coupled, perhaps, with the name of the inventor or manufacturer.

41. The distinction between *ordinary* and *quick-acting* operating systems lies solely in the movement.

42. Ordinary mechanisms are operated in not less than three motions, viz., rotation, translation, and swinging, accomplished by continued revolutions of some crank, or by crank and actual hand movement in a relatively slow manner. Each motion is a distinct operation, even though accomplished by a continued movement of the crank.

43. Quick-acting breech mechanisms are worked by the simple swing of a lever, requiring less than a complete turn to completely open or close the breechblock, the motions being accomplished quickly and continuously. There may be three motions, as in the ordinary system, but in all later-designed breech mechanisms there are but two—rotation and swinging. For heavy guns a crank may be used with interposed gearing, on account of great weight; but this crank must have only a limited movement, so that a hand lever could be substituted for it and the gearing without reducing the time of the operation, provided a corresponding direct power be applied to it.

44. It may be noted here that the names of the subdivisions of the systems given above are sometimes used with reference to the manner in which the ammunition is put up or loaded. Such names give the name to the gun.

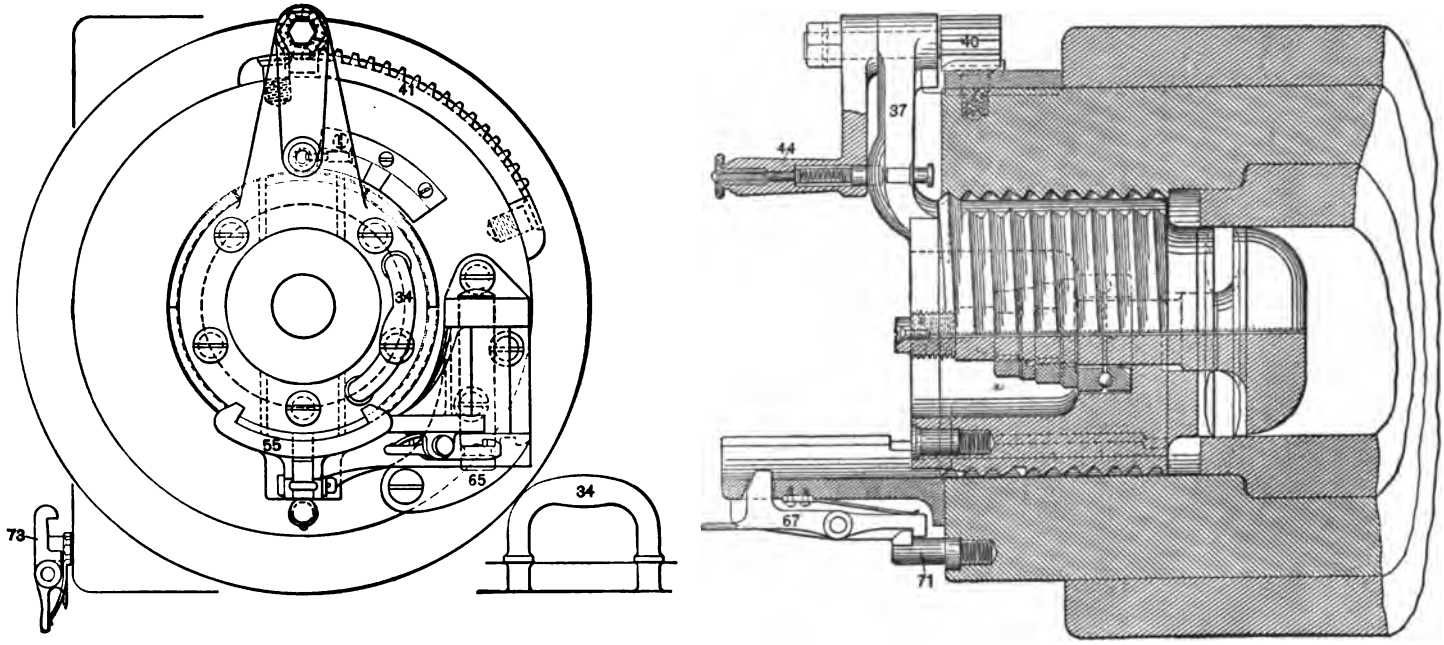
45. Even the gun carriage sometimes gives the name to the gun. Thus, a rapid-fire gun may be so called from the fact that fixed ammunition is used, but it would still be possible to use an ordinary system of operation of the breech mechanism, and a slow-working gun movement, and vice versa. Properly speaking, however, a rapid-fire gun would not only use fixed ammunition, but a quick-acting breech mechanism, and be mounted on a quick-working gun-mount. Thus the terms "rapid-fire gun-mount," "rapid-fire breech mechanism," "rapid-fire guns," have arisen.

46. Types of the ordinary system of operation.—There are three types: (1) Service; (2) modified Farçot; (3) improved Farçot. The difference between (2) and (3) is so slight that it is usual to class both under (2).

47. The service type is exemplified in the 6-inch Mark III, 8-inch Mark II, 10-inch Marks I and II, and 12-inch Mark II breech mechanisms. The 6-inch and 8-inch represent one method, the 10-inch Mark I a second method, and the 10-inch and 12-inch Mark II a third.

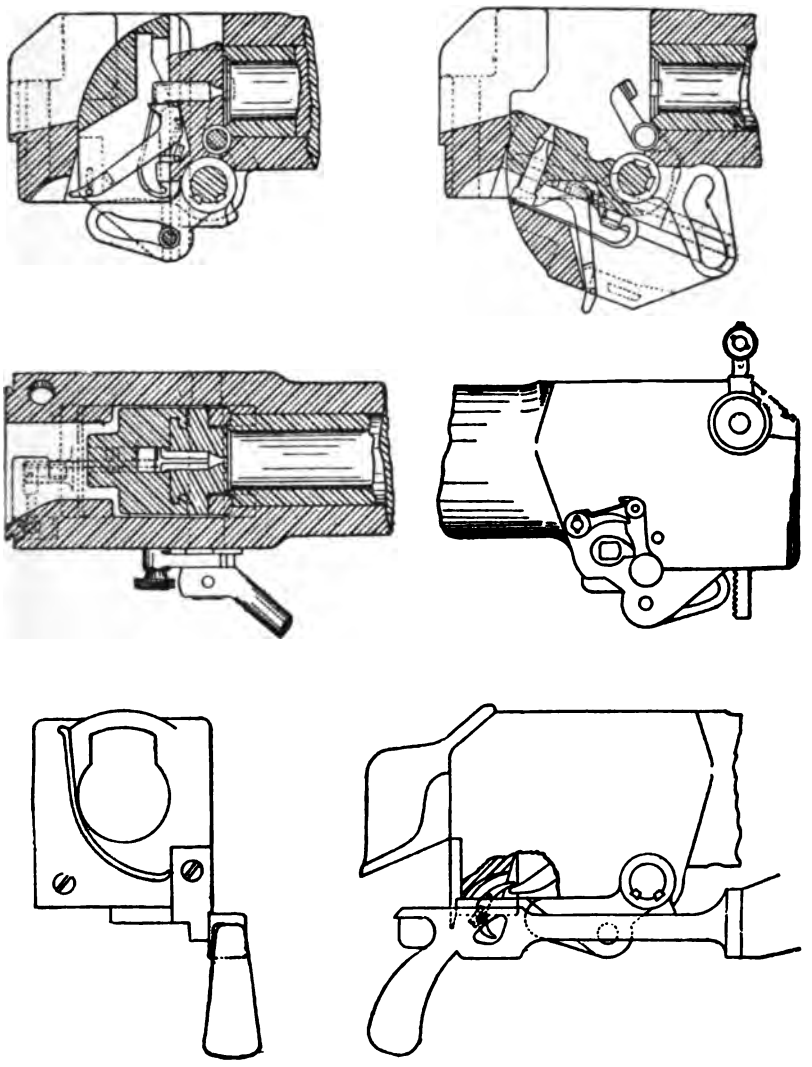
(1) *In the first,* a lever is secured to the rear face of the block, and carries a small pinion (operated by a crank) that engages in a circular rack secured to the circumference of the breech; on turning the pinion the block revolves, locking or unlocking the threaded sections. The block, being unlocked, is withdrawn into a tray hinged to one side of the gun; (in the 6-inch it is withdrawn by hand, in the 8-inch by a translating screw in the tray). The block and tray are then swung clear of the screw-box by hand. Other suitable devices are used in connection with latching the tray, keeping the plug locked, etc. This operating system is shown in the 6-inch mechanism (Plate V). Many guns were formerly so fitted, but all have now been "converted" into rapid-firing guns, with a quick-acting system.

(2) *In the second method,* the pinion is on the breech face of the gun, and a circular rack is screwed to the rear face of the block. The block, being unlocked, is started out by a cam on a lever pivoted to the rear face of the block and working against the gun, and is then withdrawn by hand onto a carrier hinged to the gun-mount, the gun being at extreme elevation. The carrier



"ORDINARY" BREECH MECHANISM FOR 6-INCH B. L. R., MARK III.

34. Grasp.
55. Plug-tray.
37. Plug-lever.
65. Hinge-bolt.
40. Plug-lever pinion.
41. Rack.
41. Rack.
71. Tray-catch.
44. Plug-lever crank-handle.
73. Back latch.



NORDENFELT BREECH MECHANISM.

or tray is then moved to one side by a hydraulic or a pneumatic motor.

(3) There is but little difference between the third type and the modified Farçot type.

48. The Farçot types are much alike and are fully described in the following chapter. The name Farçot is from the inventor, a Frenchman, and the modifications are not very distinctive, being mainly in the direction of simplifying the manufacture. One improvement, however, originated by Lieut. Fletcher, gives greater power to unlock by giving a more oblique inclination to the unlocking teeth; the original gear had far too little power in this direction and it was this change that really made the system successful in this country.

49. Types of quick-acting systems.—There are four principal types: (1) Rapid-fire; (2) Semi-automatic; (3) Automatic; (4) Machine-gun breech-actions.

(1) A *rapid-fire* breech mechanism is a quick-acting one, *without a gas-check*. It is provided with an extractor and special firing mechanism for use in guns using primed metallic cartridge cases; or, in other words, for rapid-fire guns.

(2) *Semi-automatic rapid-fire* breech mechanisms are quick-acting, part of the operation being by hand and part automatic. This gives rise to the name; it also names the gun as semi-automatic.

(3) *Automatic rapid-fire* breech mechanisms are those in which all the operations are performed automatically by utilizing the energy of recoil. The name also defines the gun.

(4) *Machine guns* necessarily have quick-acting systems, generally actuated by hand power.

50. Mechanism for B. L. Rs.—It has been noted that some B. L. Rs. have "ordinary" and others "quick-acting" breech mechanisms. The latter are practically the same as the rapid-fire type so far as the operating gear is concerned, and no special name is needed for them. The old term "quick-fire" has been abolished for breech mechanisms as well as for guns.

Names of Breech Mechanisms.

51. We have seen that there are three general systems used in connection with breech mechanisms: (1) System of breechblock; (2) system of operation, (3) system of gas-check. There is still another that might be added—"the firing mechanism." As the latter two may differ in the same general make-up, they are not considered. The name or designation may be given for either of the first two systems or both, or for one of their subdivisions. The general rule may be said to be:—For all quick-acting breech mechanisms, the name is that of the inventor, to which may be appended whether rapid-fire, semi-automatic, automatic, machine, etc., or simply the mark; for others, the system of breechblock operation, followed by the particular mark—or simply the mark—is given; the latter has been alluded to before. The former will follow thus: "Dashiell 4-inch, rapid-fire breech mechanism, Mark III" or "Mark V," or simply "Mark III or Mark V breech mechanism, 4-inch"; "13-inch breech mechanism, Mark II," or "Mark II breech mechanism, 13-inch breech-loading rifle"; "12-inch breech mechanism, Welin type," or "Mark VI breech mechanism, 12-inch breech-loading rifle."

52. The names of quick-acting breech mechanisms in United States Navy.—(1) Hotchkiss rapid-fire, (2) Driggs-Schroeder rapid-fire, (3) Dashiell rapid-fire, (4) Fletcher rapid-fire, (5) Elswick or Armstrong rapid-fire, (6) Vickers, (7) Maxim-Nordenfelt rapid-fire, (8) Nordenfelt rapid-fire, (9) Haeseler rapid-fire, (10) Lynch rapid-fire, (11) Semi-automatic guns of the Hotchkiss, Maxim-Nordenfelt and, a few, Driggs-Seabury patents; (12) Maxim-Nordenfelt automatic, (13) Colt automatic, (14) Hotchkiss revolving cannon, (15) Gatling.

53. Only two guns of the Lynch type have been manufactured, and the system is similar to the Hotchkiss.

54. Of the above types Nos. 1, 2, 3, 4, 5, 6, 11, 12, 13, and 15 will be described in succeeding chapters. Nos. 8 and 9 are briefly described below.

55. Nordenfelt rapid-fire system (Plate VI).—The mechanism consists of the following principal parts: *Action-lever, action-cam, breechblock, wedge, extractor.*

(1) The *action-lever* has a vertical one-third circle motion from front to rear. It is one piece with the main axis.

(2) The *action-cam* is connected to the main axis and has a slot, a part of which is concentric with the arc described by the action-lever. On the rear upper part of the cam is a bearing corresponding to one on the under part of the trigger.

(3) The *breechblock* carries the firing-pin, mainspring, and trigger. The firing-pin has beveled projections or cocking-lugs on its base for the wedge to act on, and on its under part is a lug by which the trigger retains it. The mainspring is flat, of great power and strength. The trigger pivots on its pins, and its motion is regulated by a safety-lug, moving round a corresponding lug on the wedge. On the arm of the trigger are two lugs, one above and one below, the former is acted on by the wedge, the latter by the action-cam.

(4) The *wedge* has a vertical motion in the breech; its lower end is a pin which fits in the slot of the action-cam.

(5) The *extractor-lever* is connected to the double extractor, working on both sides of the cartridge case. The tongue of the extractor-lever abuts on the extractor-cam lever, which is on the main axis.

56. Action of the mechanism.—The action of the mechanism is as follows:

For opening—

(1) The lever carries the action-cam slot over the action-pin in the part which is concentric to its own motion, and therefore no movement of the mechanism takes place.

(2) The part of the action-cam slot which is not concentric to its own motion now engages the action-pin, forcing the wedge down, which, acting on the beveled firing-pin projections, forces it back and compresses the main or firing spring. When the firing-pin lug is clear of the trigger, the wedge bearing acts on the upper-trigger lug, forces up the trigger, which catches and retains the firing-pin.

(3) When the action-pin has reached the end of the cam-slot, the extractor-lever begins to be forced back by its tongue, being met by the raised portion of the extractor-cam lever, and the empty cartridge case is thus slowly started. The action-pin having reached the end of the action-cam slot, the lever still moving back causes the breechblock to rotate and fall back to the rear, and, at the latter part of this movement, brings the tongue of the extractor-cam lever in contact with the extraction-lever, and thus throws the empty cartridge case rapidly to the rear. The lever is now at its farthest position to the rear.

57. *For closing—*

(1) The breechblock is brought up and carried forward, pushing a fresh cartridge into the barrel.

(2) The cartridge being quite home, the action-cam slot engages the action-pin in the part of the slot which is not concentric, and forces the wedge up into position; the action-pin then passes into the concentric portion of the action-cam slot.

(3) The forward motion of the lever continuing, the bearing on the action-cam is brought into contact with the under lug on the trigger, pushing the trigger up, thus relieving the firing-pin and firing the gun.

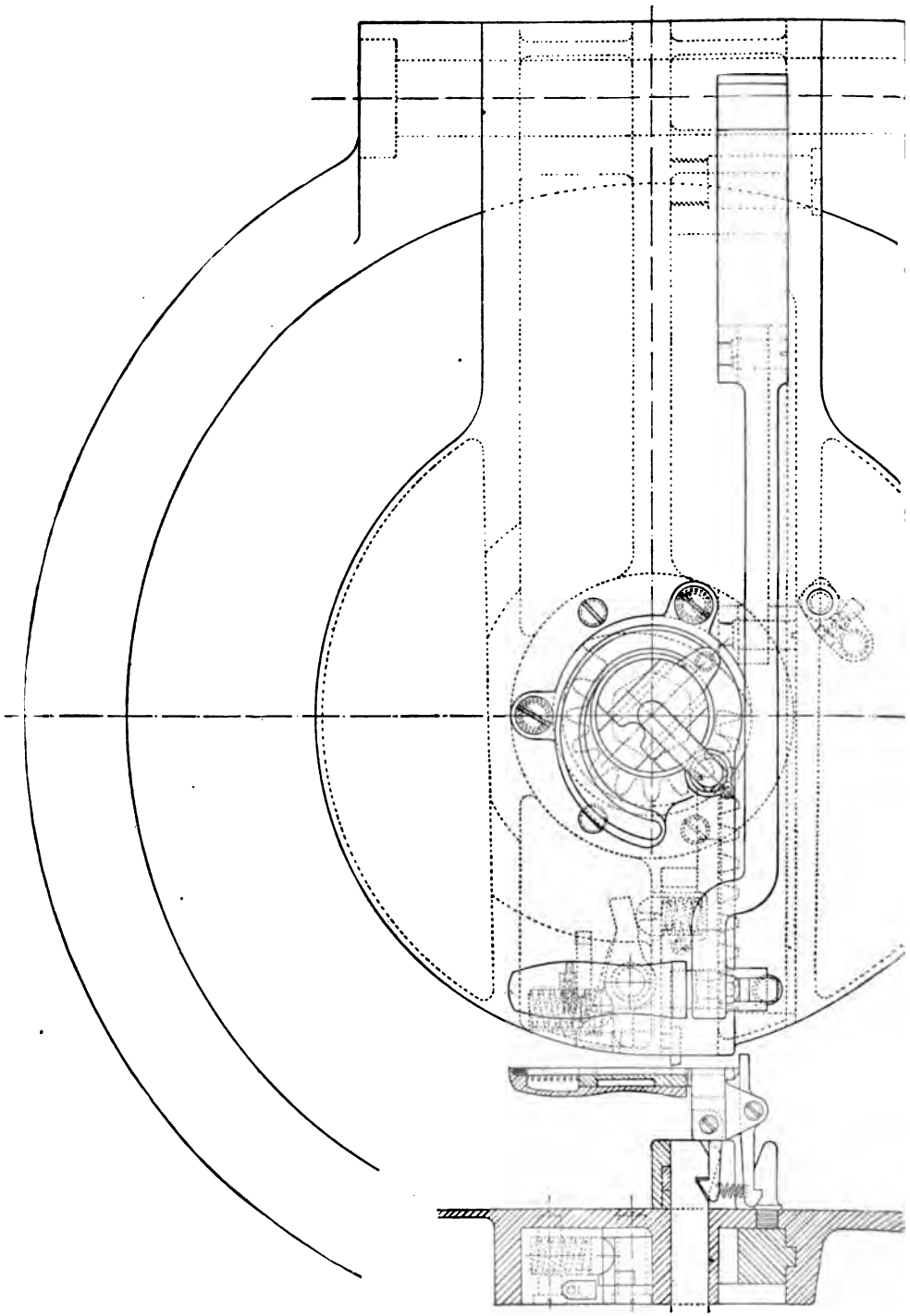
58. The gun cannot be fired before the breech is secured by the wedge:

(1) Because the inclined surface inside the wedge is formed in such a manner that the firing-pin cannot be made to strike the cap of the cartridge until the wedge is quite home and supported by the entire bearing surface. If the trigger is pulled before the breech is secured, the cocking-lugs on the firing-pin strike on the inclined surface of the wedge and the point cannot strike the cap of the cartridge.

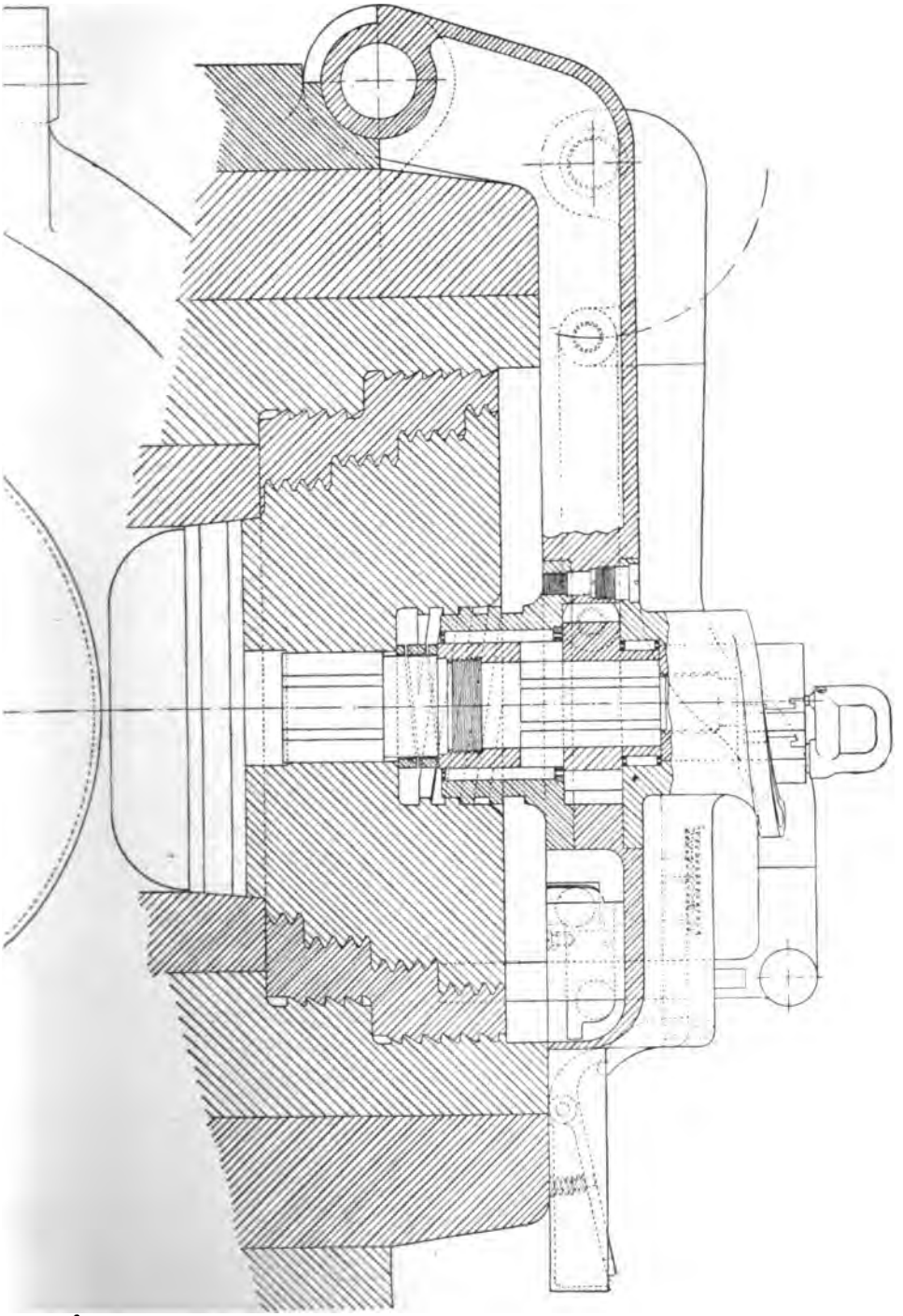
(2) The safety-lug on the trigger is behind the corresponding lug on the wedge until the wedge is fully home, and consequently the sear-nose of the trigger cannot be forced to release the firing-pin before the breech is secured.

59. The Haeseler system.—(Plate VII.) The spiral-threaded breech-block, shown as fitted with the De Bange gas-check, is recessed out in the rear portion. It bears on an axial stem which passes through a boss secured to the front face of the "carrier-plate," by which the block is supported and on which the revolution takes place for locking and unlocking. On the outer surface of the carrier-boss is a square thread (same pitch as the plug thread), which engages a female thread in a piece secured to the front end of the block's recess, so that, when the block revolves, it is advanced or withdrawn to the point of engaging or disengaging the spiral threads of the block and screw-box. On the rear end of the stem is keyed a pinion allowing a free longitudinal movement of the block. The pinion works within a vertical slot in the carrier, and has no longitudinal movement. This "rotating pinion" is divided into two sections of unequal diameter; the smaller section has the larger diameter and is plain, while the larger has a periphery equal to the length of the rotation-rack (about three-fourths circumference), on which are teeth. A transverse "rotating-rack," having vertical teeth that engage those of the rotating-pinion, slides right and left in a guide groove in the carrier beneath the center. The right end of this rack is connected to the hand-lever by a horizontal link, with vertical axis. The operating lever is hinged to the right side of the carrier and has a vertical hand-grasp on the left end. The carrier-plate is hinged to the gun by a vertical hinge-bolt.

60. *The operation* is as follows: The breech being closed, first, by pulling the hand-lever to the rear, a stop-bolt in the carrier is withdrawn from a longitudinal cut in the block and screw-box. (This is called the locking-bolt, and is designed to lock the block to the screw-box in the closed position, from any revolution.) Then the link pulls the rotating-rack to the right, which results in revolving the block to the unlocked position, at which movement the back of the lever brings up on the shoulder of the lug to which it is pivoted, the rotation is stopped, the center of motion is transferred to the carrier's hinge-bolt, and both the block and carrier



HAESELER 8-INCH B



EECH MECHANISM.

swing out from the breech. The swinging is arrested by an extractor-cam, rigidly fixed to the carrier, bringing up on the end of the extractor, which, in the swinging movement, has been moved to the right until the edge of the extractor-lock in the gun is reached. Then a lug on the extractor also brings up on the side of the gun, and is designed to relieve the extractor-pin from the moment the block is unlocked. A pin on its rear face is caught by a spring device, to prevent revolution of the block in the carrier when out of the gun. The catch retaining the block from rotation is not tripped until the carrier-plate reaches the breech face.

61. The first movement of the block to revolve, either for locking or unlocking the threads, is accomplished with great power, as the rotating-rack works on the ends of the pinion's large diametrical section. The speed of revolution and amount of turn necessary to lock or unlock the block may be varied according to design.

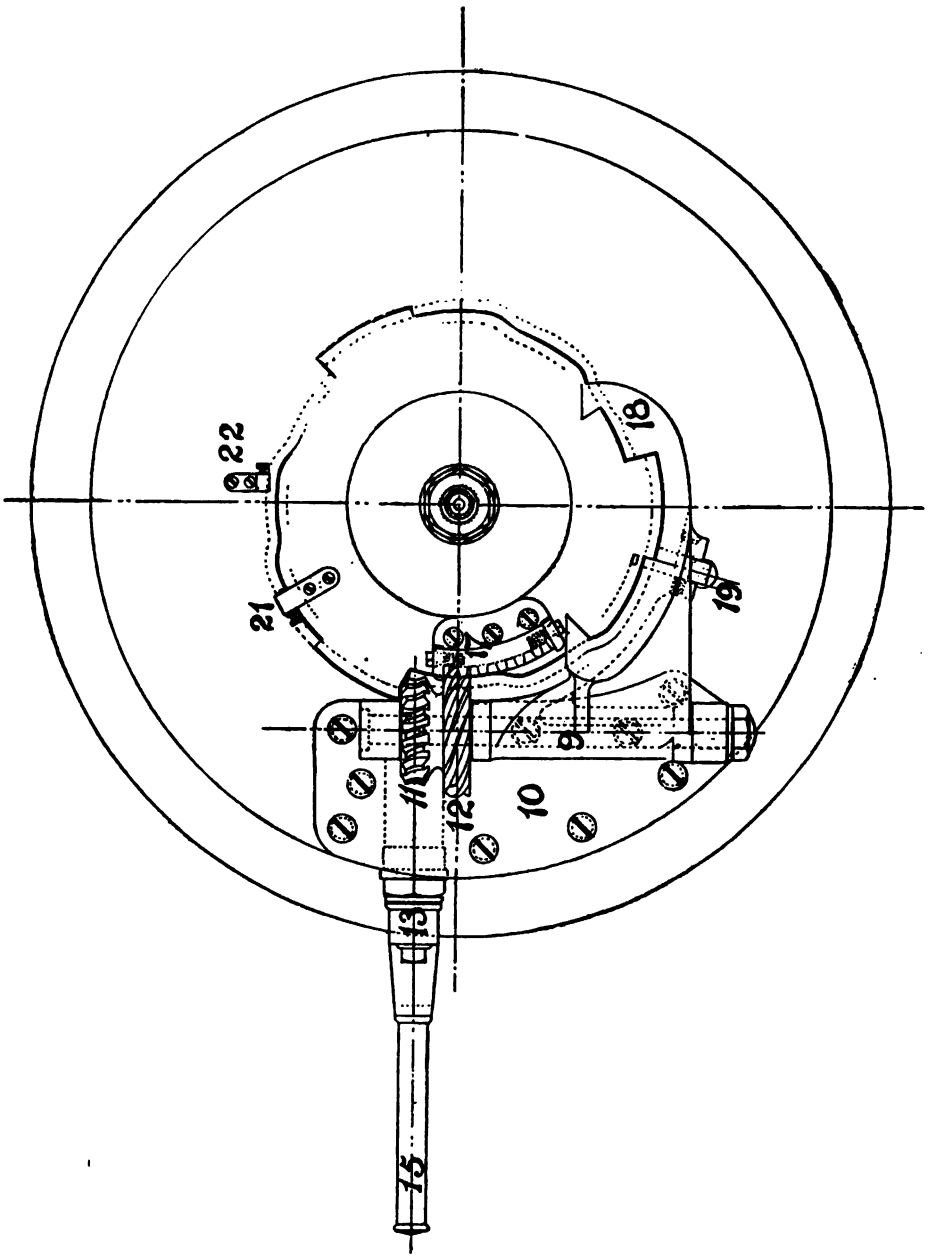
CHAPTER V.

12-INCH MARK VI BREECH MECHANISM FOR 8-INCH, 10-INCH, AND 12-INCH GUNS.

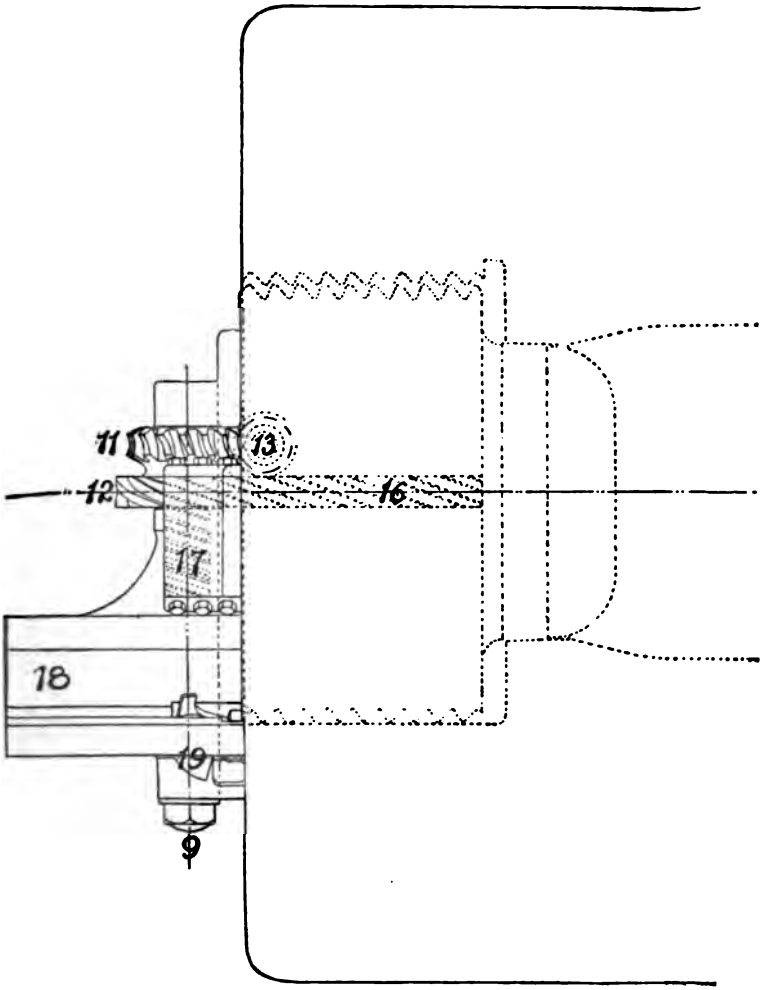
1. The 12-inch Mark VI breech mechanism is fitted to the later high-powered guns of 8-inch, 10-inch, and 12-inch calibers.

2. The breechblock (1) (see Plate III) is of the "Welin" type, and for the 12-inch mechanism, which is the size shown in the plates, the screw-box and block are each divided into three sections; each section is divided into four steps, three of which are threaded cylindrical surfaces and the fourth a blank, thus giving the block a holding surface comprising three-fourths of its circumference. By using this, the Welin patent, a much shorter block may be used, giving greater ease of manipulation and requiring less weight both of gun and of breech mechanism. The De Bange gas-check (2), with front (3) and rear (4) split-rings, is used as previously described. The primer seat is in the rear end of the mushroom-stem (6) on which is screwed the firing-lock. The vent, or orifice through which the flame of the primer discharge reaches the powder, is through an axial hole in the mushroom-stem. The mushroom (5) with gas-checking pad and rings is secured to the block by the locking-nuts (7) screwed on the mushroom-stem; during the process of locking and unlocking, the block is revolved about the mushroom-stem, and for this reason a ball-bearing washer (8) is inserted to reduce friction. Plates I, II, and III show the block (in its unlocked position) in rear elevation, side elevation, and in horizontal cross-section respectively.

3. The operating gear is of the system known as the "Improved Farçot Gear," which is in all the essentials the same as the "Modified Farçot;" the latter differs principally in having its hinge-pin turn *with* the spiral pinion. The name *Farçot* is from the inventor; Lt.-Comdr. F. F. Fletcher worked it out,



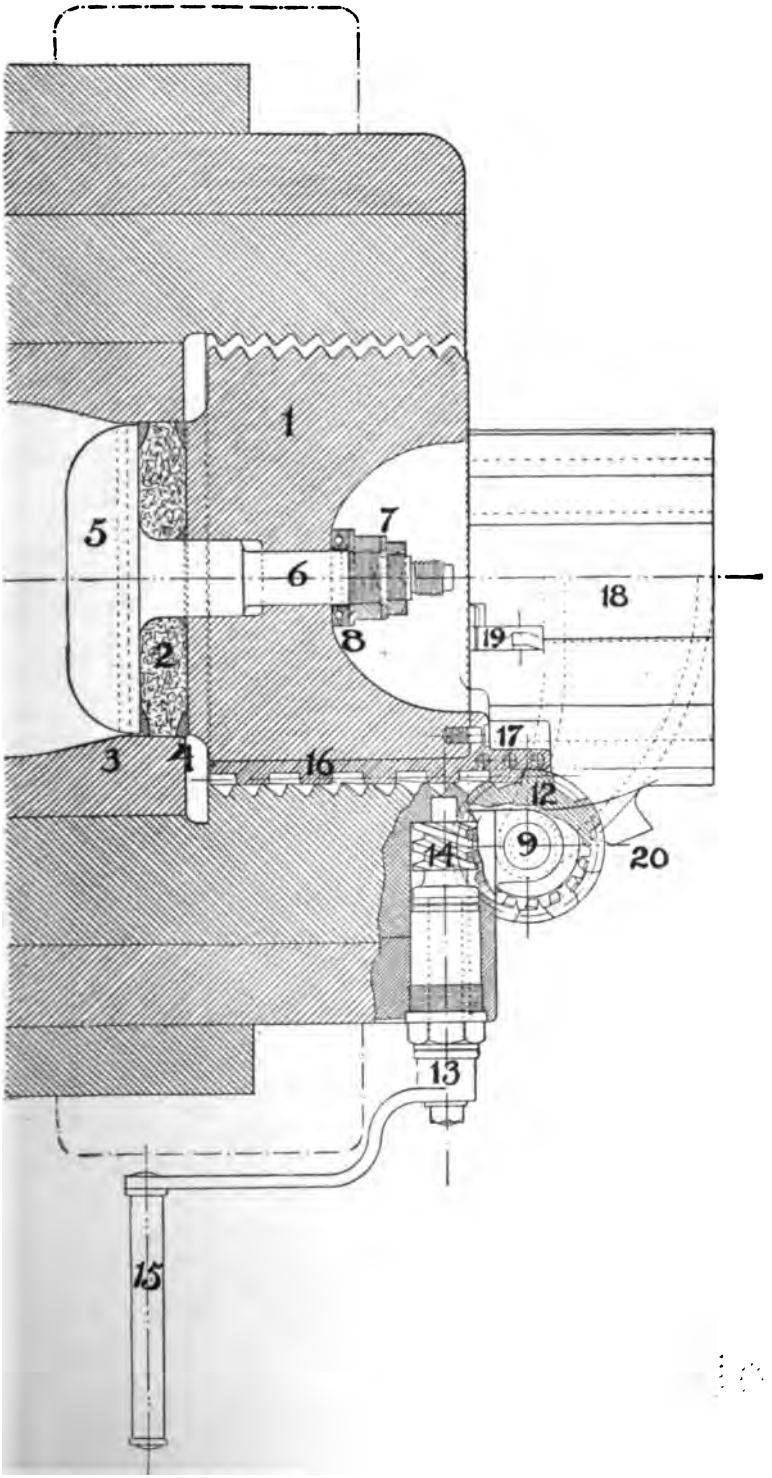
MARK VI BREECH MECHANISM FOR 12-INCH GUNS.



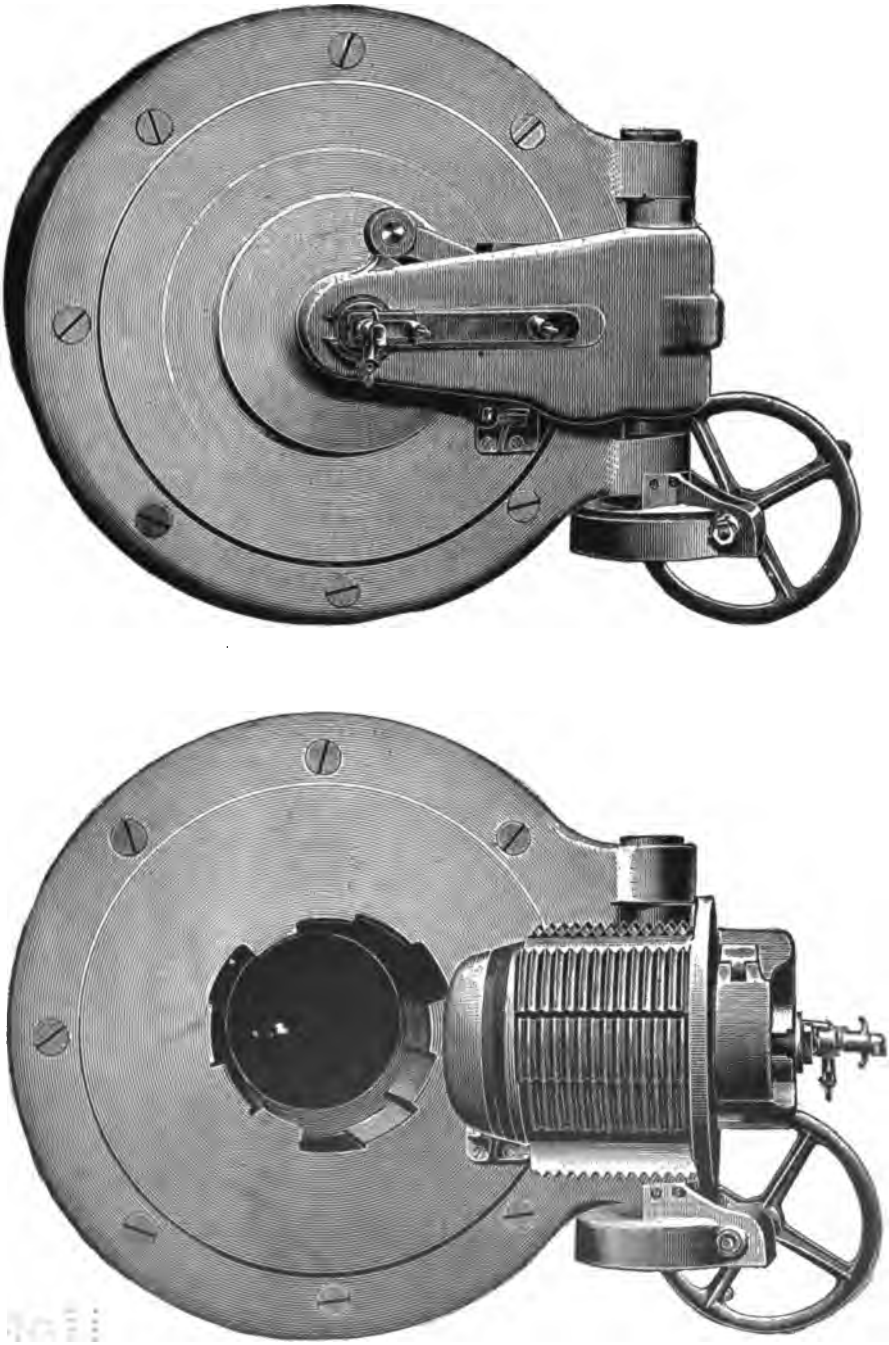
MARK VI BREECH MECHANISM FOR 12-INCH GUNS.

improved it and adapted it to the U. S. naval guns, and it is sometimes called the " Fletcher system." Obviously, with a breech-block of large size there must be three steps in the operation while closing or while opening: (1) *rotation* about the axis, which locks or unlocks the threads of the block and the threads of the screw-box; (2) *translation* along the axis of the bore of the gun between the positions of locking and of swinging; (3) *swinging*, by which the block is swung on a vertical hinge into or out of the line of the bore. In this system of operating gear, the three steps are accomplished in either direction by the continuous rotation of one crank, other movements being automatic; seven turns of the crank suffice to operate a 12-inch mechanism, which is a near approach to " quick acting."

4. Operation.—The operation of *opening* the breech is as follows: A vertical shaft (9) (see Plates I, II, and III), also acting as a plug-tray hinge-pin, is journaled in a lug on a hinge-plate (10) bolted to one side of the gun's breech face; the shaft itself carries on its upper end a worm wheel (11), and, on its central part, in a horizontal plane through the gun's axis, a spiral pinion (12) with teeth inclined 20 degrees to the horizontal. A horizontal crank-shaft (13) is journaled in the upper end of the hinge-plate, or partly in the gun, or entirely in the gun if there is no hinge-plate. It has a worm (14) that engages the worm wheel, and is actuated by a crank (15) on the outer end. Turning the crank will thus turn the vertical shaft and the spiral pinion. There is a system of spiral teeth, also inclined 20 degrees, cut on a rack, part of which is longitudinal (16), dovetailed and recessed lengthwise into the plug, and part circumferential (17), or " fan-shaped," generally extending to the rear of the plug and secured to the rear face thereof. The spiral pinion engages this rack helix. On turning the crank, if the plug be locked, the spiral pinion engaging the circumferential or segmental rack will revolve the plug to unlock the threaded sections, and when this is accomplished the rotation is stopped by a suitable stop-plate secured to the segment. The continued movement of the crank will now cause the pinion to act on the longitudinal part of the rack (rotation being prevented by the edge of recess), and withdraw the plug onto the tray (18). When the plug is completely withdrawn, the tray-latch (19) is



MARK VI BREECH MECHANISM FOR 12-INCH GUNS.



BREECH MECHANISM FOR 12-INCH BRITISH NAVAL GUN.

automatically released, at the same time locking the plug on the tray, the movement of translation is changed to swinging, and the plug and tray swing out clear of the breech about the vertical shaft, until brought up by the stop (20). The tray-latch performs the double duty of holding the tray to the face of the breech while the mechanism is closed, and at the proper time, releasing it and locking the block to the tray. In *closing* the breech all the steps are carried out in the reverse order.

5. The breech mechanism of earlier B. L. Rs. are in most respects similar to the above except that the French interrupted screw or "ordinary" breechblock is used. The block is made to swing either way and in turret guns it always swings away from the center of the turret. Plate IV shows the breech mechanism of a 12-inch British naval gun in the closed and open positions. The block is also of the Welin type but the operating gear is considerably different from the one described above.

6. The Mark VIII firing-lock (Plate V).—"Combination" primers, which explode either by percussion or by an electric current, are now used in all B. L. Rs. and the Mark VIII lock has been designed to work in either manner without requiring changes or adjustments of any of its parts; the lock is in itself a breech mechanism of the sliding-wedge type. In the plate, Figs. 1, 2, and 3 are longitudinal sections, Figs. 4 and 5 are cross-sections, and Fig. 6 is a rear elevation; the lock is shown in its closed position with hammer down.

(1) The *receiver* (1), or main body of the lock, is screwed on the rear end of the mushroom-stem and is secured by the spring locking-catch (28) which enters a square slot in the stem; the primer is supported in its seat in the mushroom-stem by the wedge (2) which closes behind it and is worked up or down to its closed or open position by twisting the hammer-stem (6). Surrounding this stem and secured to it by a feather is a gear wheel (31) that connects through the idle gear (32) with a vertical rack on the left side of the wedge, by which the latter is operated. The friction-pin (3), being pressed against the wedge by a spiral spring, drops into a recess and aids in holding the lock closed. The extractor (18) is normally held against the stem by its spring (19); when the wedge moves downward, the pawl (26) strikes the lower end of the extractor and ejects the primer case, after which the pawl

slips by and the extractor is snapped back into place by its spring. In a recess in the wedge is placed the insulated firing-pin (14) with its point resting against the primer and affording at its rear end a contact point for the hammer; the spring (37) exerts its force to hold the pin *away* from the primer.

(2) The *hammer* (5) is mounted on the hammer-stem (6), which turns in and moves back and forth in a tube cut in the left side of the receiver. When firing by percussion, the hammer, after closing the wedge, is drawn to the rear, compressing the firing-spring (25) until the point of the sear (24) catches in a notch at about the middle point of the stem and holds the hammer in the cocked position. The firing lanyard is hooked to the trigger (21); no spring, other than the sear itself, is used in the sear and trigger device. The wedge cannot be operated when the hammer is cocked. When firing by electricity, the hammer is left in the position shown, after closing the wedge, thus establishing an electric connection from the contact-lug (21) (Plate I), through the contact-pieces (8 and 9) and the firing-pin, to the primer. The sleeves of insulation (10, 11, and 17) are made of vulcanite.

(3) *A short wire* makes the connection between the binding-post (12) and the contact-lug (21). To the other lug (22) is connected the electric-firing wire; the two lugs touch and complete the circuit only when the breechblock is fully closed, and the only break in the circuit is then at the firing-key. Premature firing by *electricity* is therefore impossible, but if the primer is put in place and the hammer cocked when the breech is open there is danger of premature discharge; for this reason, while firing by percussion at least, the gun should be primed and the hammer cocked only after the breechblock is entirely locked. Obviously this is a safe practice even when firing electrically (because of the percussion feature of the primer), and is the plan now followed.

(4) *An improvement* made in 1902, called "Modification I," prevents the wedge from being jarred open by the shock of discharge. In 1903, Lieut. Graeme made a change in the hammer-stem which prevents the hammer from being in line with the firing-pin while being cocked or eased down from the position of full-cock. With this modification, the gun cannot be accidentally fired by percussion by the hammer slipping from a man's fingers while he is cocking or easing down the lock.

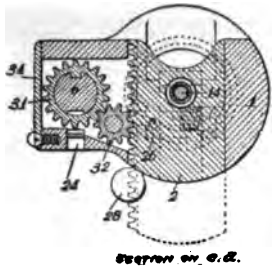


FIG. 4.

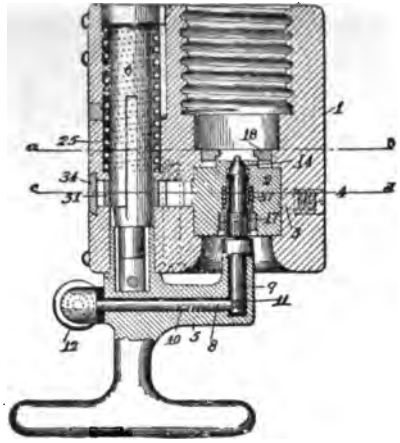


FIG. 1.

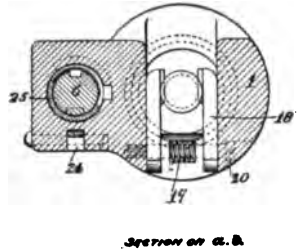


FIG. 5.

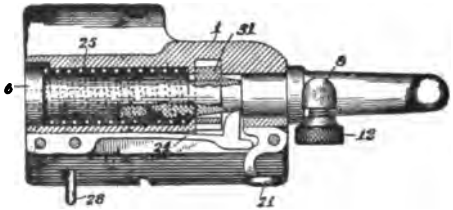


FIG. 3.

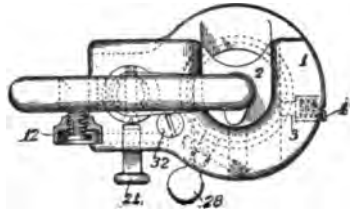


FIG. 6.

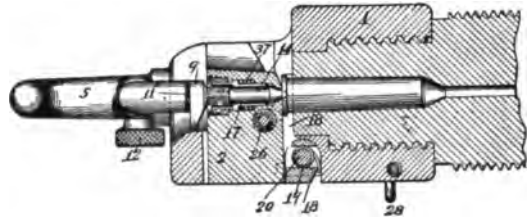


FIG. 2.

THE MARK VIII FIRING LOCK.

CHAPTER VI.

BREECH MECHANISMS FOR 5-INCH, 6-INCH, AND 7-INCH GUNS.

1. Cartridge cases.—The first modern 5-inch and 6-inch guns were fitted with De Bange gas-checks and used brown powder in bags. The breech mechanisms were slow-acting, and the residue from the powder necessitated sponging between rounds. The adoption of cartridge cases, either loaded separately or as fixed ammunition (with the 5-inch gun) was thought to be a great advantage, and their use became general.

2. Disadvantages of cartridge cases.—It was soon discovered, however, that the use of cartridge cases presents certain disadvantages:

(1) They sometimes stick in loading or in extracting.

(2) They increase the loading interval by the time required to remove the case.

(3) They encumber the deck after prolonged firing.

(4) Their weight is considerable, and is charged to the ammunition supply of the ship.

3. The adoption of a smokeless powder, which leaves no residue of combustion in the gun, has made it possible to discard cartridge cases and return to the former method of loading the powder charge separately in a bag,—placing the primer in the breechblock. Since a quick-acting system of operation was retained, the change has resulted in no increase in the firing-interval; 6-inch B. L. guns have fired eleven aimed shots per minute in target practice, and the disadvantages of using cartridge cases have been eliminated.

4. The breech mechanisms for the 5-inch Mark IV, the 6-inch Mark VI, and the 7-inch Mark I differ only in minor respects. A 5-inch mechanism is shown in its closed position in Plates I and II. In Plate I, Fig. 1 and Fig. 2 show rear and horizontal

profiles of the mechanism, Figs. 3 and 4 show the connections of the firing wire, and there are enlarged detached views of some of the working parts. In Plate II, Fig. 1 shows a vertical longitudinal section of the mechanism; Figs. 2, 3, 4, and 5 are views of the firing-lock, being respectively a rear elevation, a horizontal section, a vertical-longitudinal section, and a vertical section through the hammer-stem.

5. The mechanism has the Welin breechblock, operated on the Vickers' system, fitted with a service designed firing-lock. The principal parts of the mechanism are: The breechblock with mushroom and gas-check; the carrier; the operating lever and pinion with rotating-arm and rotating-link; the loading-tray, and the firing-lock.

6. It is to be noted that:—

(1) The screw-box is cut in a ring of metal (*A*) which screws into the jacket, abutting against the rear face of the tube, and is secured from turning by sunken screws.

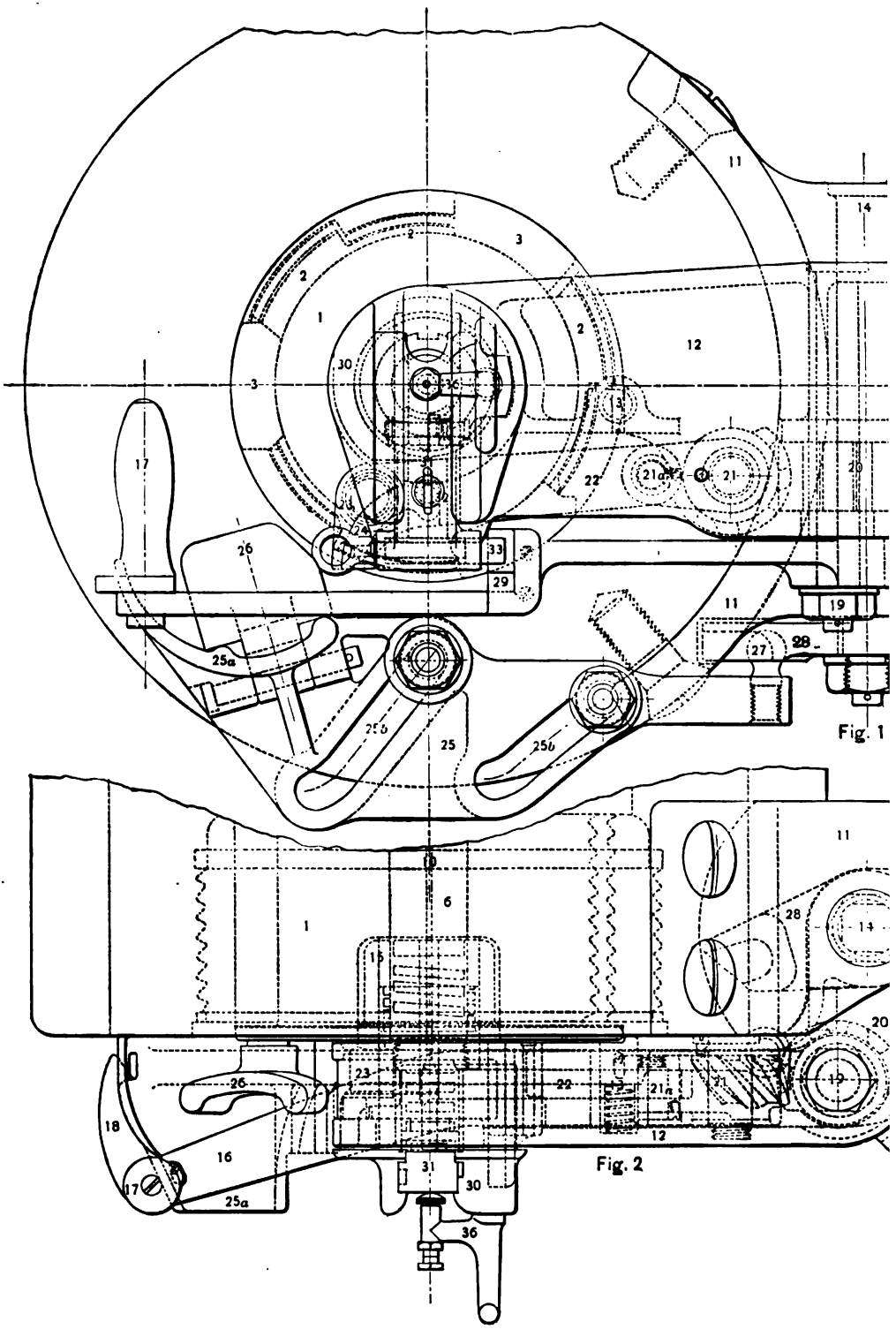
(2) The opening or closing of the breech involves only two steps, viz., *rotation* and *swinging*, there being no *translation;* to enable the block to swing directly in or out of place on the carrier hinge-pin, the blanks of the block and screw-box, and, to a slight degree the threads, are sloped away, forming curved surfaces which have the hinge-pin as a center.

(3) A loading-tray is attached to the breech of the gun and is worked automatically by the operating gear.

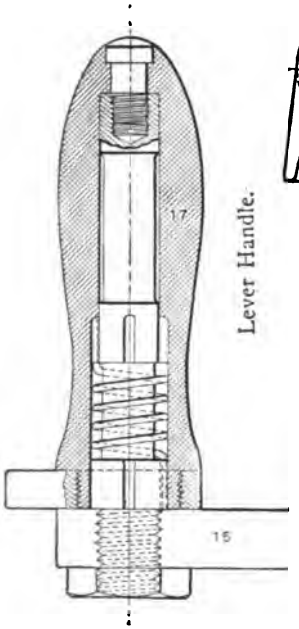
(4) The gun uses "combination" primers and no change or substitution is required in the firing-lock when changing the method of firing; the lock is opened, closed, and the primer-case ejected, automatically.

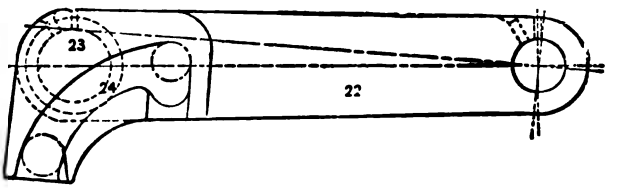
Breechblock and Operating Gear.

7. The breechblock (1) (see Plate I), of the Welin type, is divided circumferentially into three sections, each of which are in turn divided into three steps. The lowest step, or one of least radius, is left blank (3), and on the other two are cut screw-threads (2) of slight pitch; a narrow gap is left between the steps for convenience in manufacture. On the rear end of the

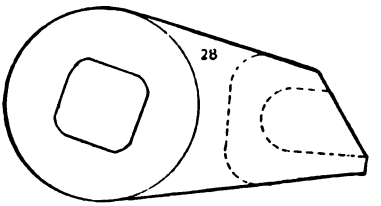


5-INCH BREECH MECHANISM. MARK IV.





Rotating Link.



Loading Tray Lever.

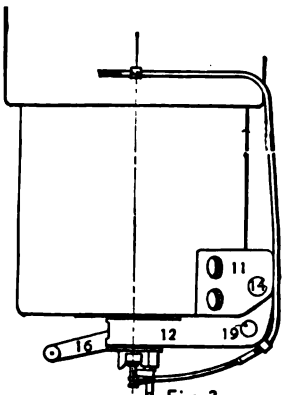
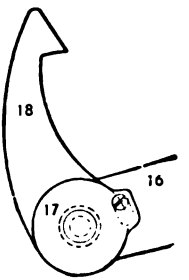


Fig. 3



Lever Lock.

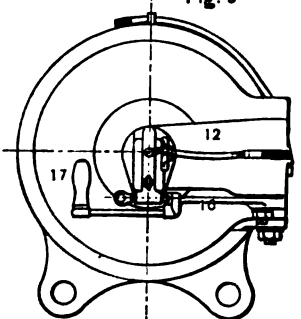
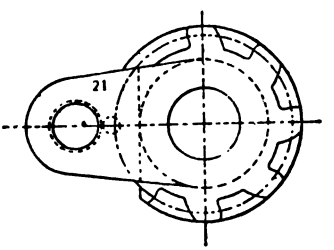


Fig. 4



Rotating Arm.

block is left a narrow collar which is of about the same radius as the highest step and is of the same pitch as the threads of the block; it brings up against the rear thread of the screw-box as the block swings into place. A circular recess is cut in the right lower edge of the block (between the blank and the thread) into which the locking-plunger is forced. The block is bored through longitudinally, forming a recess through which the mushroom-stem (6) passes; the latter is in turn bored through, forming the primer seat and vent (10).

8. The gas-check, of the De Bange type with front (8) and rear (9) split-rings, is compressed between the front face of the block and the mushroom-head (5). The latter is secured to the block by a nut (6a) on its stem; the spring (6b) is held between the nut and a bearing surface on the block in such a manner as to compress the gas-check pad; the compression is regulated by the amount the nut is set up. The rearmost portion of the plug is still more cut away around the mushroom-stem to receive the boss (15) of the carrier; the recess runs well into the block and has chased on its surface an interrupted thread (with two blanks), of square section which has the same pitch as have the threads of block and screw-box. Four collars of square section but without pitch, also interrupted, are cut on the rear end of the mushroom-stem upon which the firing-lock is secured. The rotating-stud (23) is screwed into the rear face of the block.

9. The carrier (12), a brass L-shaped arm cored for lightness, is hinged to the lug (11) by the vertical hinge-pin (14). It contains a slot in its right lower portion in which the operating-lever and pinion are pivoted on the vertical hexagonal bolt (19); also a recess in which the rotating-arm (21) works on a horizontal pivot. Above and a little to the left is situated the locking-plunger (13) which is pressed forward by a spiral spring, its motion being limited by a stop-screw. From the forward side of the carrier, a boss (15) projects forward, to which the block is secured by an interrupted-screw thread as described above. The boss is bored out to permit the mushroom-stem to extend to the rear for the attachment of the firing-lock.

10. The operating gear includes: the *lever* (16) and the *rotating-pinion* (20) rigidly connected to each other by their hexagonal

hinge-pin (19) and working in the horizontal plane; and the *rotating-arm* (21) and *rotating-link* (22), which work in the vertical plane.

11. The *lever* (16) is a long steel bar, having at its left end the handle (17), within which is a spiral spring that actuates the lever-lock (18) to secure the lever to the loading-tray, as shown by the plates. The lever-arm curves sharply at about its middle point, forming a cam-groove (29) whose function lies in operating the firing-lock. The *rotating-pinion* (20), working on the same pivot with the lever and above it, has 45° "skew"-teeth cut around the greater part of its periphery.

12. The *rotating-arm* (21), working on a horizontal pivot, has, on its right and lower sides, "skew"-teeth which gear with those of the pinion (20); its left side is drawn out to form an arm two inches in length. The *rotating-link* (22), entirely unattached to the carrier, is hinged to (21) by the horizontal pin (21a) and has in its left end a socket which receives the rotating-lug (23). There is also a cam-groove (24) in the rear face of the link which, with the cam-groove (29), operates the firing-lock.

13. The loading-tray (25) is an irregularly-shaped brass casting held to the lower part of the face of the breech by two bolts working in curved slots (25b). The tray proper (25a) is at the left side of the casting—when the breech is opened it lies on a level with the bottom of the gas-check seat. The hinged lip (26) drops down, when the projectile is inserted, to protect the screw-box, and automatically hinges itself up when the tray is lowered. In the left edge of (25a) is cut a notch over which the lever-lock hooks. The *loading-tray lever* (28), fitting over a square section on the lower end of the hinge-pin, and turning with it, has in its end a recess which engages the stud (27) of the loading-tray.

14. The operation of the mechanism, not considering the firing-lock, comprises only *rotation* and *swinging*, and is performed as follows. *To open:*

(1) The handle of the operating lever is grasped and turned to the left, releasing the lever-lock, and the lever is then swung to the right until the carrier strikes against the hinge-lug (11), bringing the face of the block about parallel with the axis of the bore. *Unlocking:* As the lever is swung to the right, the pinion

(20) turns with it and, gearing with the teeth on the hub of (21), throws the left end of the arm downward; this draws the link (22) and consequently the lug (23) to the right and the block is rotated against the hands of a watch. This motion continues until the lug (16a) brings up against the carrier and the unlocking is completed. *Swinging:* The center of motion now changes to the hinge-pin (14) and the block swings out of the gun on its carrier; when the latter leaves the face of the breech, the locking-plunger (13) springs forward into a recess in the rear edge of the block and holds it securely from further rotation while the breech is open. As soon as the block is clear of the gun, the loading-tray lever (28) engages the lug (27) and pulls it to the right; the motion of the tray being constrained by the shape of the slots (25b), it also rises, as well as moving to the right, so that, when the bottoms of the slots (25b) strike the bolts, the tray is in position for loading.

(2) *To close: Swinging.* The lever being swung to the left, the loading-tray is first moved down out of the way by the lever (28) before the block gets to it. At the end of the swinging movement, the rear thread of the plug strikes the rear screw-box thread, the locking-plunger is forced rearward out of its recess in the block, leaving the latter free to begin—*locking.* The motion of the lever being continued on (19) as a center until it lies against the carrier and locks itself to (25a), the operating gear acts in the reverse direction to rotate the block to its locked position.

The Firing-Lock.

15. The lock, known as the Mark IX lock, is adapted for combination primers to be fired either by electricity or by percussion; it is intended that, as far as possible, all firing be by electricity and that percussion firing be regarded as an alternative. The Mark IX lock (see Plate II) is in principle very similar to the Mark VIII lock described in the preceding chapter, though it is greatly different in external appearance; it is, however, operated automatically instead of by hand and it is principally in this feature that the two locks differ from each other.

16. The receiver (30) is secured to the mushroom-stem by

interrupted collars, and its rear portion is larger than that of the Mark VIII lock—to accommodate a longer wedge. The wedge (31) extends well below the center of the breechblock and has in its lower portion the pin (32), which engages the cam-groove (24) of the rotating-link, and the pin (33) which engages the groove (29) of the operating lever. Both of these pins are held against their cammed surfaces by spiral springs, as shown in the plate, and are so fitted that they may be retracted against their springs and turned until lugs (32a and 33a) enter grooves (31a) in the wedge by which they will be held out of action; the lock must then be operated by hand. In other respects, the wedge with its firing-pin (35), extractor (34), friction-pin, etc., is like that of the Mark VIII lock. The hammer (36), firing-spring, sear (37), trigger (38), gear wheel, and idle gear are also unchanged. The firing-wire is attached to the hammer, as is shown on Plate I, Figs. 3 and 4, and the actual firing, whether by electricity or by percussion, is effected exactly as with the Mark VIII lock; the *firing* is not automatic—only the opening and closing of the lock and the ejection of the primer-case.

17. Operation.—(1) *By hand:* When the pins (32 and 33) are drawn in, out of action, the lock is operated by twisting the hammer to the right or left, while it is lowered. This may be done when the breech is closed or opened and the lock is to be operated in this way if it be desired to prime, re-prime after a misfire, or to remove the primer, *while the breech remains closed.*

(2) *Automatically:* If the pins (32 and 33) be put in action, as is intended, the lock will be actuated automatically, as follows: Suppose the breech closed and the gun fired. As the lever is brought to the rear the cam-groove (29) forces the pin (33) downward slightly, sufficiently to revolve the hammer a little, breaking the connection, but not enough to wholly open the wedge. The rotating-link, moving to the right, brings (32) downward, by the action of the cam-groove (24), and the wedge is lowered to its full travel and the primer sharply ejected. While the loading is being performed a new primer is being placed in the lock. During the first part of the *locking,* the link (22) acts in the reverse manner and partially closes the wedge, but its cam-groove has not great enough travel to entirely finish the closing. However, just

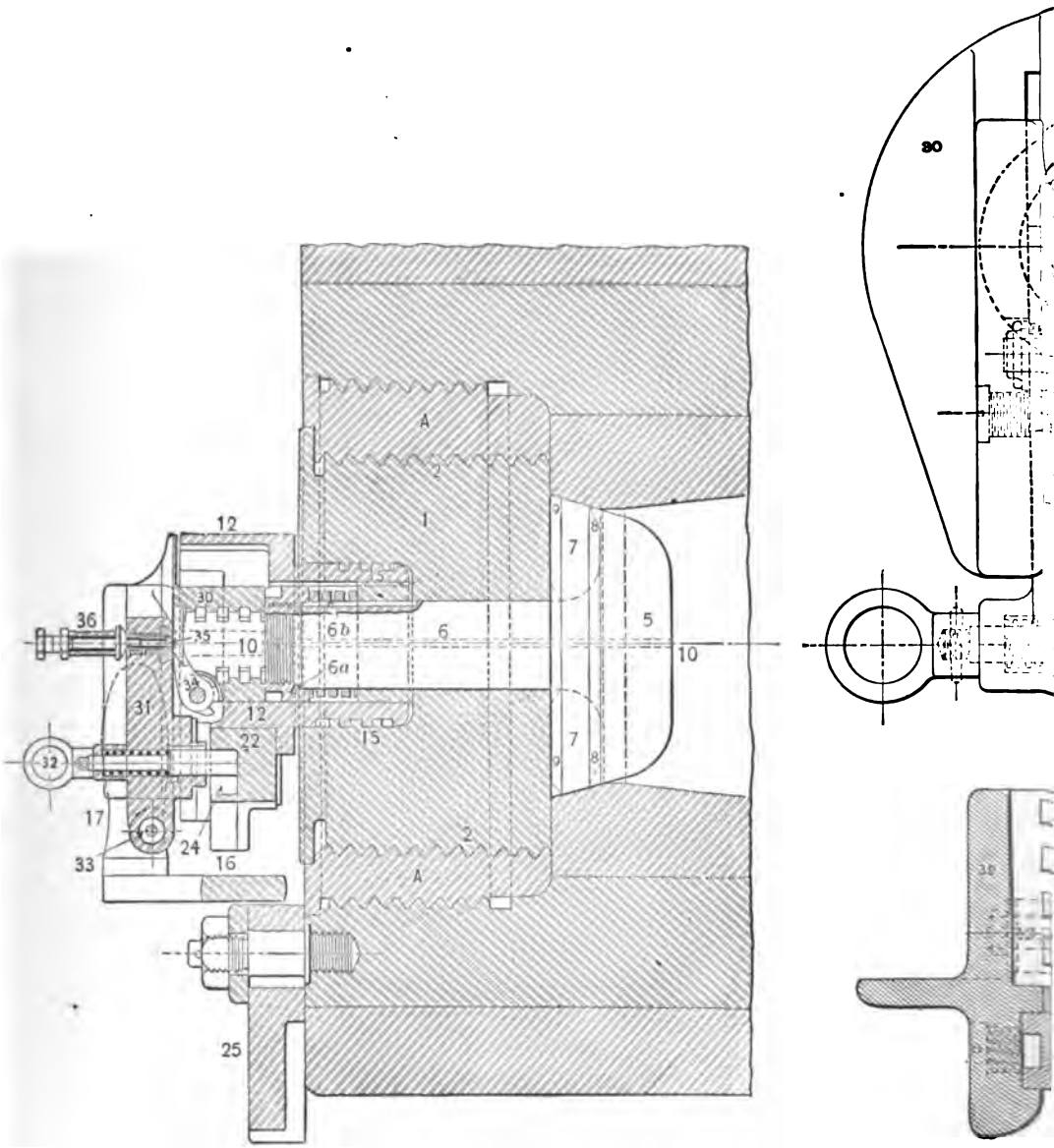


FIG. 1.

VERTICAL SECTION OF BREECHBLOCK AN

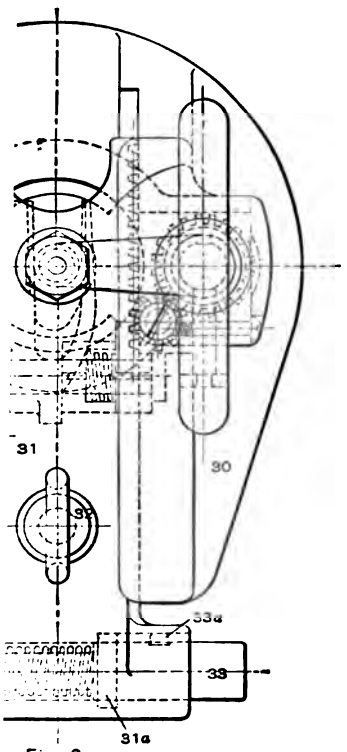


Fig. 2

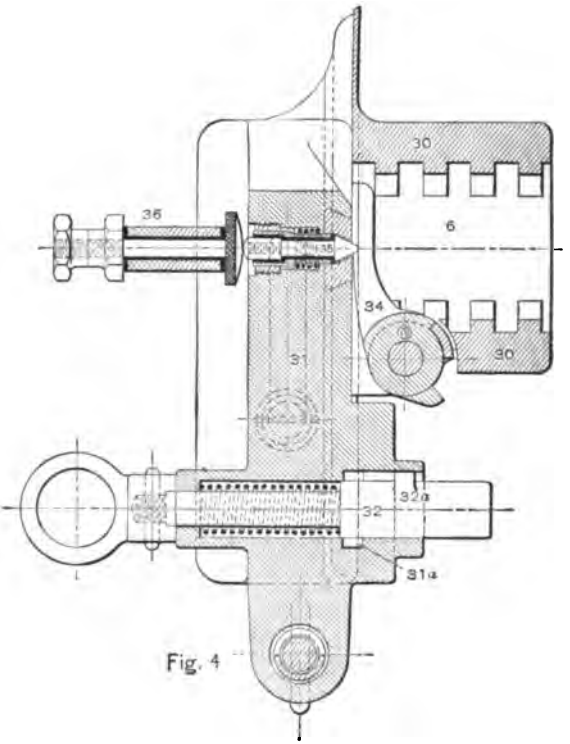
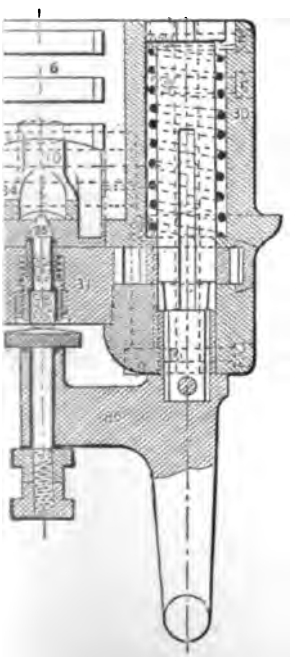


Fig. 4



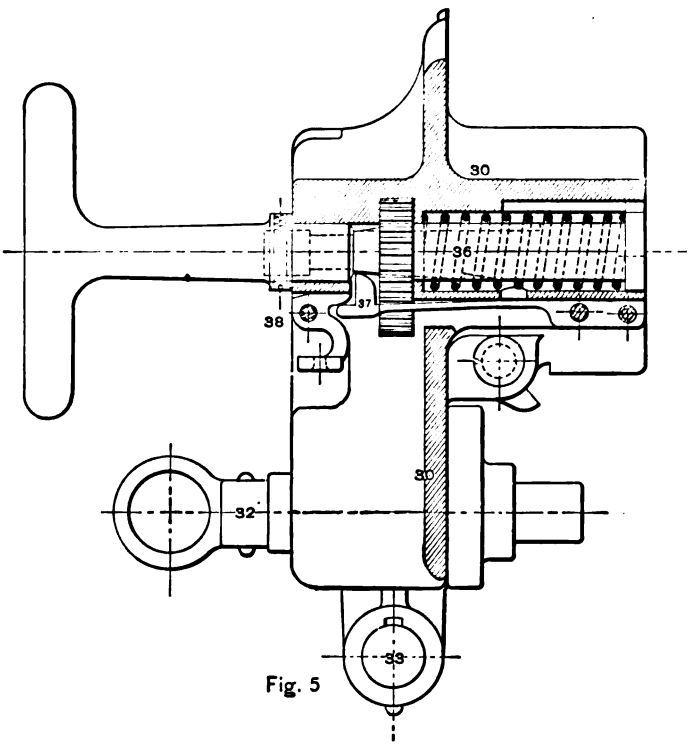


Fig. 5

3.
THE MARK IX FIRING-LOCK (ENLARGED).

as the locking of the breechblock is completed and as the lever nears the end of its swing, the cam-grooves (29) strike (33) sharply, close the wedge, and turn the hammer to its closed position, making the connection, and the gun is made ready for firing electrically. If it now be desired or be necessary, to fire by percussion, the lanyard is hooked to the trigger and the hammer cocked.

18. Safety.—*The breechblock will not open* when the gun is fired, or at extreme elevation because:

(1) No external force can so act on the block as to make the operating gear work backward.

(2) The lever-lock prevents the operating lever from swinging open unless its handle has first been twisted to the left.

19. *The gun cannot be fired prematurely,* because:

(1) The firing-point is not in contact with the primer; or

(2) The hammer with the firing-pin; and

(3) The hammer cannot be cocked until the breechblock is locked—as long as the lock is being worked automatically.

20. The 6-inch mechanism is, with the exception of one or two minor details, the same as the above.

21. The 7-inch mechanism is also similar except that the carrier, extending farther to the left, overlaps the block and engages a locking device on the left face of the breech, designed to secure the carrier to the gun while the block is swung into the screw-box.

CHAPTER VII.

THE DASHIELL BREECH MECHANISM.

1. The Dashiell R. F. breech mechanism, named from its inventor, the late Lieut. R. B. Dashiell, U. S. N., belongs to the interrupted-screw system, and its distinctive features (barring the firing mechanism) lie in the method of operating the block and in the extractor. The block is supported when withdrawn from the screw-box in a combined collar and tray, hinged to the gun, provided with an automatic tray-latch similar to other service types. All the operating mechanism is carried on the tray-casting, except the trigger, which is attached to the gun. The extractor is carried by the block.

2. This type of mechanism is fitted to one 6-inch gun, 86 5-inch guns, and 164 4-inch guns, and is for 5-inch guns the Mark II mechanism and for 4-inch guns the Mark III mechanism; a special firing mechanism is required for each of two varieties of primers used.

3. The block and screw-box, Plate I, have four blank and four threaded sections (left-hand threads); the rear thread of the block extends across the top blank in the locked position and acts as a stop, while pushing the block into the screw-box, by bringing up on the first screw-box thread. The following are the principal parts: Block and face-plate; combined collar and tray; tray-latch and spring; hinge-pin; rotating-rack; translating-arm and pin; operating lever and fulcrum-pin; extractor and spring; firing mechanism—all made of steel. The plates show the block, in its closed position, with percussion-firing mechanism; the electric mechanism is shown in a detached view.

4. The breechblock (1), threaded and slotted as above, has on its rear end a circular projection with an undercut score (9) for the upturned toe (44) of the translating-arm. The lower section of the block, in the unlocked position, is threaded; it has

a fore-and-aft groove cut through its center, to pass over the center tooth of the rotating-rack (45).

5. There is a rectangular longitudinal hole (8) through the block on the right side (in the closed position) for the extractor, a hole and dovetail (10) on the left side of the block in the transverse horizontal plane for the sear, and a slot in the vertical plane for the cocking-lever. In the axis of the block is a longitudinal circular hole (7) for the firing-pin. To the rear face of the block is secured by screws a ring called the face-plate (2), on the lower side of which, in the unlocked position, are a set of teeth (3) (to engage the rotating-rack), a latch-trip toe, and a curved bearing surface on the right side to rest on the side of the tray. When on the tray the space between the left two teeth works on the guide rib (22) of the tray. To the upper rear face of the block is secured a bracket (53) for the cocking-lever.

6. The firing-pin hole is closed at the rear end by a nut called a "firing-pin guard" (55). This nut is threaded to screw in the block, and on later mechanisms the screw is slotted so as to require only a quarter turn to put in place; a keep-screw prevents turning. A hole is cut through the guard on the left side for the sear, and a slot for the cocking-lever in the top.

7. **The combined collar and tray** (20) is in one casting, having on the right side two lugs (23) by which it is hinged to the gun; it supports the block and all parts not on the gun, and swings the whole clear of the breech for loading. The tray is provided on the underside with a lug (27) to carry the tray-latch; on the upper left side with a guide-rib (22); with a curved bearing surface on the right side to guide and support the block; with a transverse groove (24) for the rotating-rack, and with a vertical square hole near the rear end for a latch-trip toe (25).

8. On its right side the tray is hollowed out to admit the cogged arc of the operating lever; there is a vertical hole near the hinge, threaded on the bottom for the translating-arm pin (43), and a curved hole (29) in its bottom plate for the fulcrum-pin, struck with a radius having the former pin as a center. On the upper rear face of the collar is a projection containing the cocking-groove (21), the groove being undercut and closed at the top.

9. The two hinge-lugs (23) fit over a hinge-loop milled out on the right side of the gun; a vertical hole (30) being drilled through in which fits the hinge-pin (32). In the closed position of the block the center of the hinge-pin, translating-arm pin, and the fulcrum-pin are in a line parallel with the gun's axis,—one to the rear of the other in the above order. The right lower end of the tray projects beyond the gun and the transverse slot for the rotating-rack (24) extends to the end; the lower lip of this extension is joined to the tray proper and contains the curved slot for the fulcrum-pin above mentioned.

10. The tray-latch (33) is automatic, being the pioneer of such types on United States Navy mechanisms. It is fitted to the Mark III 4-inch and Mark II 5-inch guns, as follows: The latch, pivoted on its pin (35) carried by the split-lug (27) on the underside of the tray, is provided on the front end with a lever-toe called the "latch-catch" (33b) to engage the hook or tray-catch (80) in the gun, and an upper toe (33a) to rise in front of the block when on the tray and prevent its forward movement; in the right lower side is a square shoulder that is engaged by the latch-lock bolt (36). On the rear end the latch has a hand-trip (33d), and a vertical toe called the "latch-trip" (33c) to be acted upon by a toe on the face-plate in opening, to trip the latch. A flat spring (34) is secured by two screws to the underside of the tray with its front end bearing down on the front arm of the latch.

11. In the tray, at the front end on the right side of the latch, is a spiral spring surrounding a plunger (36) called "latch-lock bolt." It is provided with a small arm on the left side to secure the latch from any movement while the tray is clear of the gun, so that the plug cannot be started off by swinging over the latch-lock against the tray-latch spring.

12. The operating gear.—This consists of the rotating-rack (45), translating-arm (42), and hand-lever (37). A rotating-rack stud (79) is screwed into the breech face of the gun to limit the movement of the rack in the operation of unlocking the plug.

13. The extractor (75) is a flat bar, finishing at each end with a hook or shoulder, that passes through a fore-and-aft hole (8) in the block, clear of the threaded parts, and is held down by a flat spring (76) on its back, bearing against one side of the hole.

14. *The nib* (75a), or front end of the extractor, is broadened and suitably shaped to fit the rim of the cartridge case. A shoulder on the outer face at the forward end bears against a lug secured to the front face of the block, when the extractor is in its forward or pulling position, so that slipping off the rim of the case is prevented; but in closing, the extractor slides back to its rear position, and the nib can snap over the case's rim. An extractor-keeper screw (78) is provided, which passes through a threaded hole in the face-plate and bears the rear end of the extractor toward the center to prevent the rear shoulder (75b) from sliding within the hole in the block. The distance between the hooks being greater than the length of the block, there is a certain amount of lost motion which is utilized in the extraction, for, when the block is withdrawn, the extractor does not commence to pull on the empty case until the rear face of the block brings up suddenly on the rear shoulder, giving a hammer effect to start the case to the rear.

The Firing Mechanisms.

15. The percussion-firing mechanism consists of the following principal parts: Firing-pin; saddle; mainspring; cocking-lever; cocking-lever bracket; "sear;" sear-spring; and trigger mechanism, consisting of trigger-box, trigger, and trigger-spring, all made of steel.

(1) *The firing-pin* (46) is a straight cylindrical piece with a cone-shaped head and point (46a). It is surrounded by a spiral spring (47) that lies between the head and a loose-fitting saddle or sleeve (48) moving fore-and-aft on the shank (46) of the pin. A nut (49) is screwed on the rear end of the pin; the nut has an annular groove (49a) used as a lock-notch. The firing-pin complete slides back and forth in the axial hole of the block, partly guided by the firing-pin guard (55), and housed in by it.

(2) *A cocking-lever* (51) is pivoted on a pin in the cocking-lever bracket (53) secured to the block above the center by four screws. Its upper end works in the cam-shaped cocking-groove (21) in the collar, while the lower end is forked to fit over the saddle on the firing-pin.

(3) *A sear* (57) works to the right or left in a dovetail and hole in the rear face of the block; the inner end engages the cock-groove of the firing-pin nut, while the outer end is shaped into a toe, projecting forward, that is engaged by the trigger.

(4) The sear is guided and limited in its movement by a screw (58) passing through an elongated hole into the face-plate, and is kept to its work or pressed in toward the block's center by a flat sear-spring (59) held in a dovetail in the face-plate by a screw and bracket (60).

(5) *The trigger-box* (61) fits in a horizontal transverse slot on the left side of the gun, and is secured to the gun by screws (62). This carries the trigger (63), which is a bell-crank lever, pivoted at its elbow, the inner arm forming a rear projecting toe to engage the sear, while the outer arm is connected to the firing-lanyard which leads forward so that a pull moves the inner arm or toe to the left. The spiral trigger-spring (65) seats in a hole in the gun and bears to the rear on the trigger-arm, to keep the trigger-toe clear of the toe of the sear in operating the block. Incidentally the strength of the spring regulates somewhat the amount of pull on the lanyard.

16. The electric-firing mechanism, designed to fit the same recess in the block that the percussion mechanism is installed in, consists of a firing-case, insulated firing-pin, and an attachment-lug. The firing-case contains the insulated firing-pin, and is put on the breechblock in place of the firing-pin guard, being secured by the same screws. The attachment-lug replaces the trigger-box, and is secured by the same screws.

(1) *The firing-case* (66) consists of two tubular pieces (an axial and a radial arm) made of steel. The former has its rear end enlarged, threaded, and slotted to correspond with the firing-pin guard, the front portion fitting neatly into the axial hole in the block for the percussion firing-pin. The latter piece screws into the former near its rear end and at right angles; the hole in the rear end of the axial piece, closed by a plug, is for convenience in manufacture.

(2) *The firing-pin* (67, 68) consists of an axial (67) and a radial (68) arm, or inner and outer piece, screwed together at right angles (near one end) after being placed within the tubular

insulation (69) which is surrounded by the firing-case. Each arm consists of three parts, an inner and an outer piece joined by a spiral spring soldered over a small spindle left on each piece. The outer portion of the axial pin has the conical head and point which makes contact with the primer; the outer part of the radial pin makes contact with the contact-piece of the attachment-lug, and has a shoulder (left in turning the outer part to a smaller diameter) to keep the insulation in place. The insulation is made of vulcanite or wood-fiber tubing, as per drawing.

(3) *The attachment-lug* (70) is bored out to contain a contact or terminal piece (73) and a spring terminal-socket (72), which are screwed together and secured by the insulation (74) of vulcanite, as per figure. For guns having telescopic sights on the mount, the attachment-lug has a part leading forward to contain the spring-socket, which is joined at right angles to the contact piece. One end of the firing-wire is pushed into the spring-socket, while the other goes to the battery, one pole of which is grounded on the mount. When the breech is fully closed, the insulated firing-pin makes contact with the insulated piece in the lug and only then, so that when the firing-key is pressed, the circuit is completed and the primer exploded.

Action of the Breech Mechanism as a Whole.

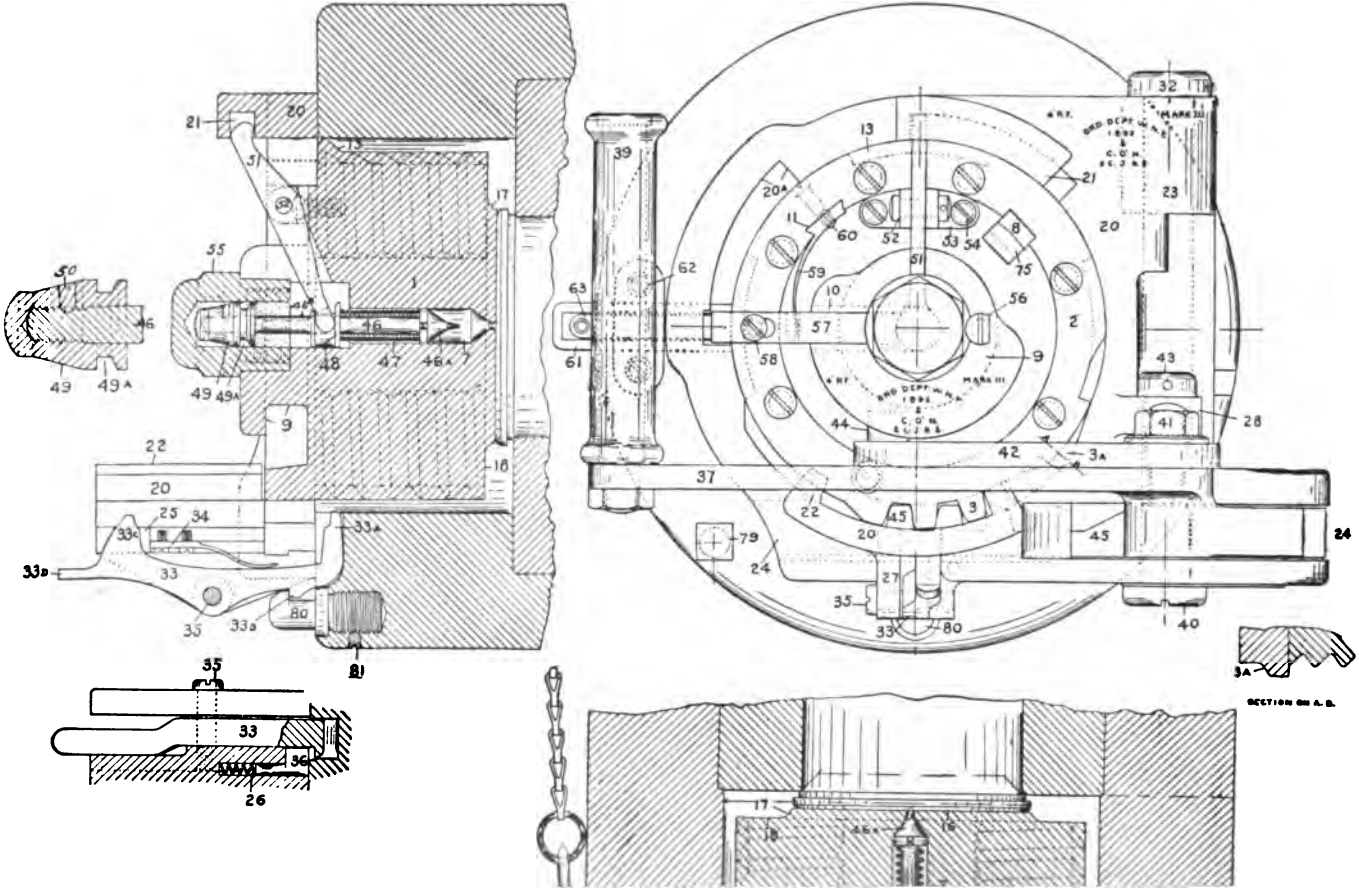
17. Opening.—(Supposing the breech closed and the hand-lever folded across the breech-face.) By the continuous swing of the hand-lever to the rear and right, the block is unlocked and withdrawn on the tray; the percussion-firing mechanism, if fitted, is cocked, the case extracted, and the block and tray swung out clear of the breech.

18. Unlocking.—The first movement of the hand-lever, on the fulcrum-pin as a center, moves the rotating-rack to the left through its cogged arc. This revolves the block until unlocked, at which point the rack brings up against the stud on the gun. During this revolution the upper end of the cocking-lever, moving in the cocking-groove of the collar, is thrown forward, which results in its forked lower end, engaging the saddle of firing-pin, moving the firing-pin to the rear until the groove in the nut is

engaged by the inner end of the sear, the latter snapping over the nut into the groove. This cocks the mechanism. The cocking-lever will now be clear of its groove in the collar.

19. Translation.—The center of the lever's movement is now transferred to the right cog immediately below the translating-arm pin, and a continued pull on the lever will result in the fulcrum-pin moving to the right in the curved slot in the tray and carrying the translating-arm with it. The hand-lever and translating-arm move in unison on the latter's pin as an axis, and the upturned toe of the translating-arm withdraws the block onto the tray. The block is guided by the rib on the tray and a blank sliding over the guide surface at the right side of the tray. It is kept from any rotary movements by the threaded section and teeth on the face-plate which lie between the tray-guides, while a groove cut in the threaded section passes over the center tooth of the rack. Near the latter part of the block's withdrawal onto the tray, a trip-toe on the face-plate (beveled off to the rear in a curve) rides over the latch-trip toe, and trips the latch. The front end of the latch, on rising, is disengaged from the tray-catch or hook on the gun and frees the tray. At the same time the latch-hook, too, rises up in front of the block and secures the latter from longitudinal movement on the tray, while the latch-lock bolt is forced out by its spring and engages *under* the shoulder left on the latch, preventing movement of the latter as long as the tray is clear of the gun's breech-face. The movement of the hand-lever and translating-arm is arrested by the fulcrum-pin bringing up on the end of the curved slot in the tray, at which moment the above operations have just taken place.

20. Swinging open.—Further movements of the lever will now result in swinging the block and tray away from the breech on the hinge-pin as an axis, until the front side of the tray's extension brings up on the side of the gun. The front face of the block will now be in a plane parallel with the gun's axis, the breech will be clear, and the gun can be loaded after the old case has been removed. If the electric-firing mechanism be fitted the contact is simply broken when the plug is revolved. It will be noticed that the hand-lever has three successive centers of rotation (41, 31, and 32) during the swing to the right.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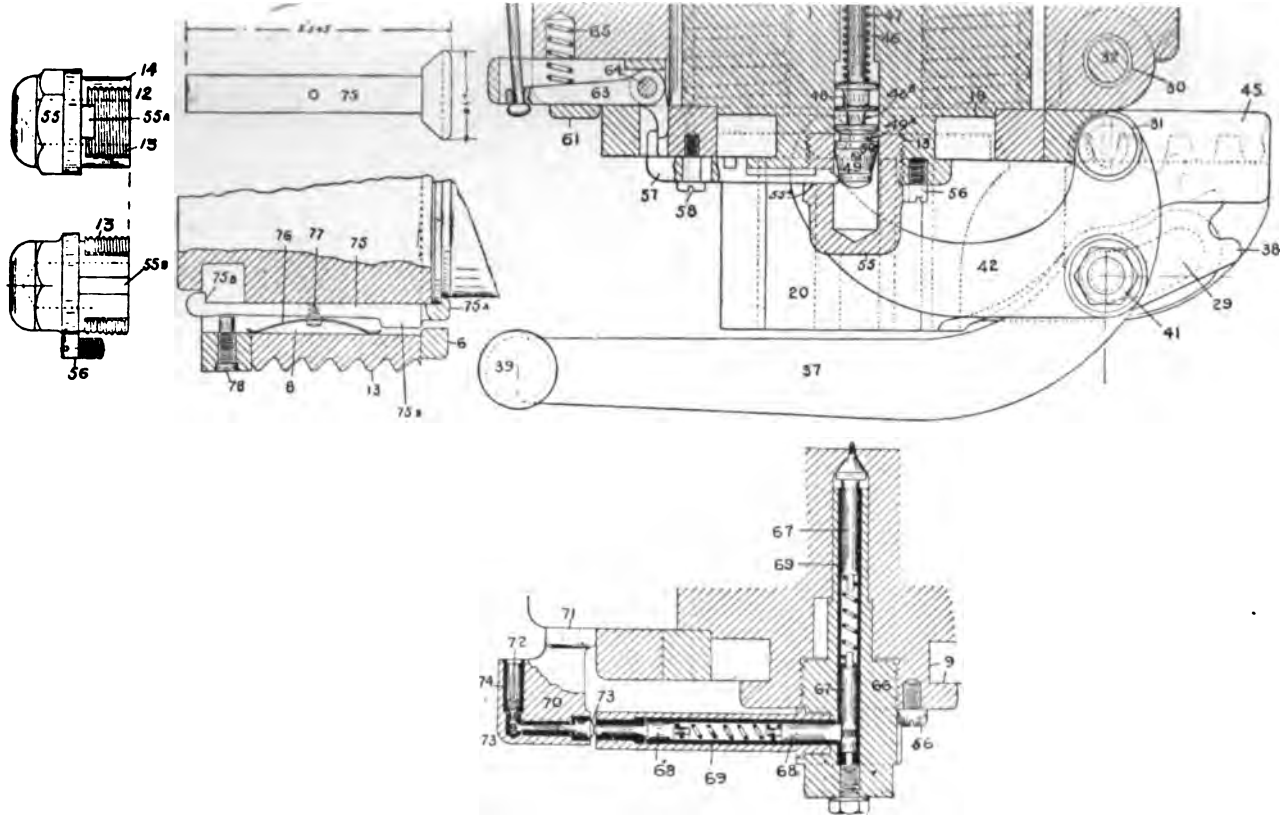


DASHIELL BREECH MECHANISM FOR 4-INCH R. F. GUNS.

Electric Firing Mechanism.

21. Closing.—*Swinging and translation.*—The reverse movement of the hand will result in the reverse operations. When the tray strikes the breech-face, the latch-lock bolt will be pushed to the rear to disengage the latch, and, if the hand-lever is worked smartly, the block will start into the screw-box, being forced in by the translating-arm, which now, with the lever, moves about the former's pin. The latch turns to engagement with the tray-catch by the action of its spring the moment the block starts to the front and clears the latch-trip toe. This frees the latch-lock toe from the block's front face. The translation of the block into the screw-box is arrested by the last thread on the block bringing up on the rear thread of the screw-box, and the fulcrum-pin having reached the end of its curved slot, it arrests the movement of the translating-arm.

22. Locking.—The hand-lever will now turn about the fulcrum-pin as a center, which results in moving the rack and locking the block; the motion is stopped by the hand-lever bringing up on the tray. During the revolution of the block the upper end of the cocking-lever, moving in the groove in the collar, is pushed to the rear. This pushes the sleeve on the firing-pin forward and the firing-spring is compressed. The last movement in closing brings the sear-toe in engagement with the trigger-toe, and until then the sear cannot be moved.

23. Firing.—On pulling the firing-lanyard attached to the outer arm of the trigger, the sear will be moved to the left, the firing-pin will be disengaged, will fly forward under the action of the spring, and strike the primer of cartridge case, firing the gun. If the electric mechanism be fitted, the last movement on locking the block results in bringing the outer arm of the insulated firing-pin in contact with the contact piece of the attachment-lug. If the circuit through the battery be completed, the gun will be fired, as the inner arm or point of the firing-pin is in contact with the primer.

24. Safety of the breech mechanism.—The breech will not open on firing on account of the reaction of the operating lever, the friction and shape of the screw-threads, and the friction of the gearing.

25. The gun cannot be fired until the breech is fully closed:

First, with the percussion-firing mechanism, because (1) the collar is so shaped that the sear has not sufficient movement until the block is fully locked when the toe on the sear comes to a cut in the collar, and this is the only position in which the trigger is engaged; (2) the firing-pin spring is not sufficiently compressed until the block is locked; (3) the firing-pin would not have sufficient throw for the point to strike the primer until the block is fully locked, as the cocking-lever holds the saddle in some intermediate position; (4) the point of the firing-pin cannot strike its primer in closing, as it is always within the nose of the block by reason of the cocking-lever bringing it to the rear in the act of unlocking. [It is possible, however, that a percussion-primer may be exploded by the blow of the breechblock while closing on the base of the cartridge case; this accident has occurred abroad with serious consequences and the danger of it exists wherever percussion-primers are used with swinging breechblocks of this or other types.] *Second,* with the electric-firing mechanism, because *no contact is made* between the firing-pin and the attachment-lug's contact pieces until the block is locked.

26. Notes on the Dashiell breech mechanism.—If the cartridge case sticks so that the extractor cannot pull it out, the breech may be opened by inserting a screw-driver as a pry between the rear end of the extractor and its hole. The extractor-nib may thus be sprung over the lip of the case and the block can be withdrawn. Then use hand-extractor.

27. Sometimes in trying to open the block after firing it may be found that it cannot be rotated by pulling on the lever. In this case, if a copper drift or piece of wood be placed against the outer end of the rack and struck a few light blows while pulling the lever, the block will be moved.

28. If it be desired to see the firing-point, open the breech, pull on the sear, then pull back the upper end of the cocking-lever. This will push the point through the nose of the block; but observe before closing again to push *forward* the cocking-lever and cock the firing-pin on the sear; otherwise the lever will not enter the groove in collar, and may be bent or broken.

CHAPTER VIII.

THE FLETCHER BREECH MECHANISM.

1. The Fletcher breech mechanism for rapid-firing guns, the invention of Lieut. F. F. Fletcher, U. S. N., belongs to the interrupted-screw system and its distinctive features lie in the method of operating the block. The block is supported when withdrawn from the gun by a collar, or carrier-ring, to which it is automatically locked by a locking-bolt which has other important functions as well; the extractor is pivoted in a slot through the jacket of the gun and is not carried by the block.

2. The Fletcher system, which is the last in which two varieties of primers, with a special firing mechanism for each, are employed, is more recent and, at the time of its adoption, succeeded the Dashiell system; the operating system is distinctive and requires few parts. The Fletcher mechanism is fitted to 34 4-inch guns, known as the Mark IV 4-inch mechanism; to 113 5-inch guns, known as the Mark III 5-inch mechanism, and to 60 6-inch R. F. guns, known as the Mark IV 6-inch mechanism. All of the 4-inch and 6-inch slow-fire guns have been converted to R. F. guns with this mechanism. The same system of operation, considerably modified, is employed in the new high-power, smokeless-powder R. F. guns of 3-inch and 4-inch caliber.

3. The block and screw-box (see Plate I) have four threads and four blanks; the threads do not occupy the entire length of the plug, the rear part being left wholly blank for the carrier-ring. The principal parts are: Block, carrier-ring, locking device, operating lever and hinge-pin, extractor and pin, and firing mechanism (percussion or electric); all parts are made of steel. To obviate the necessity of forging a lug on the right side of the jacket, a hinge-plate (4) is bolted to the rear face of the jacket to furnish a bearing for the hinge-pin.

4. The breechblock (1), threaded and slotted as above, has a

rack (2), with teeth inclined 45° to its axis, cut on its right upper quadrant in rear of the threaded portion and extending partially around the circumference. In the left hand upper quadrant of the block is cut a guide-slot extending circumferentially 45° and continued parallel to the axis for a distance equal to the amount of withdrawal of the block through the carrier-ring; at its forward end, this slot is gradually deepened and ends in a circular depression in the block into which the locking-bolt drops as the breech is being opened. Along the axis of the block is cut a longitudinal circular hole for the firing-pin; its rear end is partially closed by an adapter-nut when using the electric-firing mechanism (it is not shown in Plate I, but a later model is shown in Plate II which indicates the thread for the adapter-nut). The rear end of the block is also slotted through along its vertical diameter, when closed, to form a recess in which the cocking-bar of the percussion-firing mechanism works.

5. The carrier-ring (6), hinged on the right side upon the same pin (7) around which the operating lever (9) turns, is cut on its inner circumference with blanks and raised portions to allow the block to move forward and back in it. The carrier-ring (6) is slotted through radially in the upper left quadrant for a locking device which locks the carrier-ring to the gun when it is swung to and locks the block in the carrier-ring when the former is withdrawn. Thus, in this system, the carrier-ring acts as collar and plug-tray combined, and no part of the mechanism, with the exception of the operating lever, projects rearward from the face of the breech when the mechanism is closed.

6. The cammed recesses (68) on the inside of the carrier-ring receive and actuate the ends of the cocking-bar as the plug is rotated.

7. The locking device in the carrier-ring (6) consists of a lever (18) pivoted at its center, with a spiral spring (20) under its left end and carrying a locking-bolt (16) on its right end; the upper end of the bolt locks the carrier-ring to the gun when the mechanism is closed and its lower end locks the block to the carrier-ring when open.

8. The functions of this device are most important since, besides performing all the duties of the tray-latch in the Dashiell

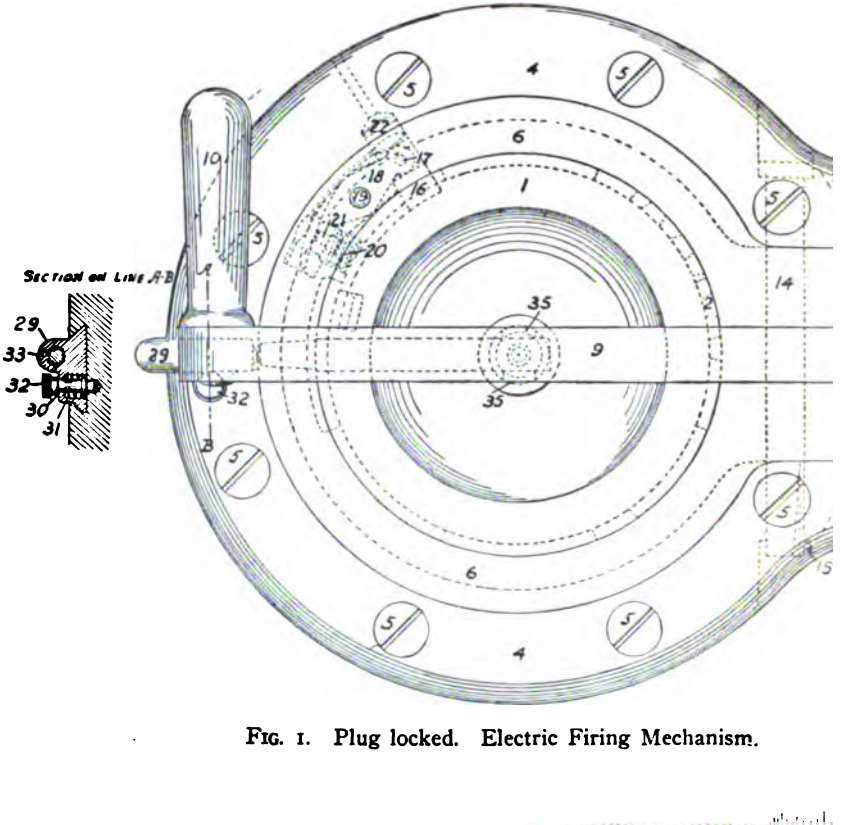


FIG. 1. Plug locked. Electric Firing Mechanism.

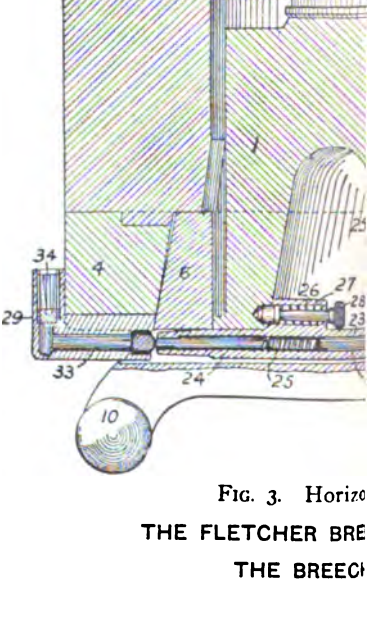


FIG. 3. Horiz

THE FLETCHER BRE

THE BREECH

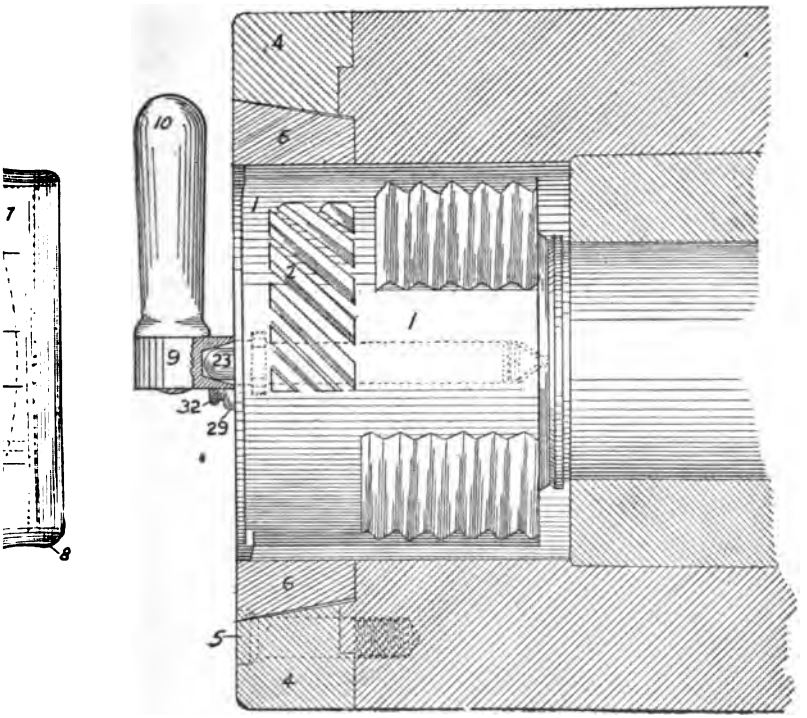
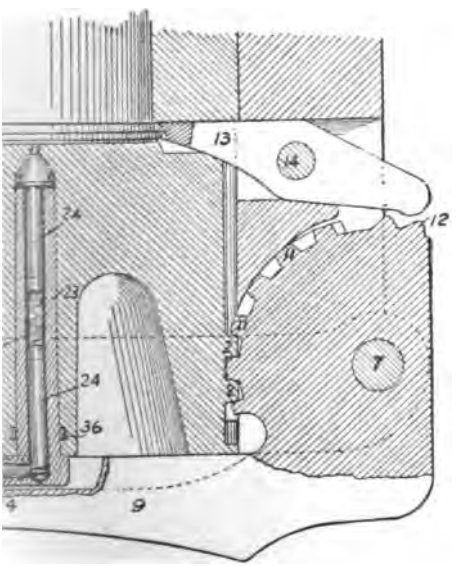


FIG. 2. Plug locked.



ntal section.

ECH MECHANISM.

I BLOCK.

mechanism it also guides the block and fixes the instant of changing the *swinging* movement to *translation*, etc.

9. The operating lever (9) has a handle (10) riveted to its left end and pivots on the hinge-pin (7) on the right side of the breech. Its rear right-hand surface is shaped to act as a cam on the outer end of the extractor (13), and its front right-hand surface is shaped into a segment of a circle and cut with five 45°-teeth (11) to fit the circumferential-rack teeth on the block and with four vertical teeth (12) of the same section as the *threads* of the block.

10. The extractor (13) is a lever turning about a pin (14) through its center and cut on its inner end to fit under the rim of the cartridge case.

Operation.

11. The operation of the mechanism in one direction comprises, as in the Dashiell system, three steps—*unlocking, translation,* and *swinging* open, or vice versa. The action of the system, excluding, for the present, consideration of the firing mechanism, is as follows:

12. Opening.—The block being closed and locked, the locking-bolt (16) has its inner end at the upper end of the circumferential part of the guide-slot in the block, and its outer end engaged in a recess (22) in the hinge-plate (4), thus locking the carrier-ring (6) to the breech of the gun; the rear tooth on the lever (9) is engaged with the lower tooth of the circumferential rack (2) on the block, and the extractor-claw is under the rim of the cartridge case. The lever (9) is swung to the right, through an angle of 59°, thereby successively engaging its teeth (11) with those of the rack (2) on the block and causing the latter to rotate 45° to the left, disengaging its threads from those of the screw-box and leaving it free to be withdrawn. At this moment the locking-bolt (16) reaches the end of the circumferential part of the guide-slot in the block and thus prevents the latter from being rotated farther. At the same instant the first of the withdrawing-teeth (12) on the lever has come opposite to the middle of a threaded portion of the block, and on continuing the rotation of the lever these teeth successively engage the threads of the block and so

cause the latter to move to the rear through the carrier-ring (6); the locking-bolt (16) now moving in the portion of the guide-slot which is parallel to the axis of the block. An angular movement of the lever of 44° completes the withdrawal of the block. At this moment the inner end of the locking-bolt (16) reaches the depression at the front end of the guide-slot, the spring forces the other end of the locking-lever (18) up, thereby pushing the locking-bolt down and disengaging it from the recess (22) in the hinge-plate (4), and the block, locked to the carrier-ring in its withdrawn position, is free to swing open with the latter.

13. *A further rotation* of the lever of 96° swings the carrier-ring and block clear of the breech aperture. During the last 41° of this motion the rear face of the lever acts as a cam on the outer end of the extractor (13), causing it to withdraw the cartridge case, at first slowly and with great force, and then quickly.

14. *Closing.*—In the reverse operation of closing the mechanism, when the carrier-ring (6) swings to, the beveled edge of the locking-lever (18) strikes the inner surface of the hinge-plate (4) and is forced down into the carrier-ring, thereby lifting the locking-bolt (16) out of its seat at the front end of the guide-slot in the block. Then as the block moves forward, the slope of the bottom of the guide-slot (3) lifts the locking-bolt farther and forces its outer end into the recess (22) in the hinge-plate, thus again locking the carrier-ring to the breech of the gun. When the breech is closed, the teeth (11) of the lever engaging the rack (2) in the block act as an efficient lock to prevent it being rotated by any pressure on its face due to firing.

15. It will be observed that in closing the mechanism the action of the locking device is positive throughout, but that in opening, a spring (20) is required to start the locking-bolt from its recess in the hinge-plate. To provide against the unlikely failure of this spring, a small hole is bored down through the hinge-plate into the locking-bolt recess, through which any small pin or rod can reach the locking-bolt and force it down in case it sticks.

The Firing Mechanisms.

16. The electric-firing mechanism consists of a steel case (23) formed of two parts screwed together at right angles to each

other, through which extends an insulated firing-pin (24). On the radial arm of the case is a spring catch (26) for locking the attachment in place, and on the axial arm are two lugs (35).

17. The *firing-case* (23) is pushed into the block with the radial arm vertical, the two lugs entering a slot in the face of the block, and is then turned 90° to the left, the lugs (35) turning into a recess (36) so as to prevent the case from being blown out; the spring catch then holds it in the proper position. In the later type the recesses (36) are replaced by the adapter-nut (not shown) which is to be screwed on when substituting electric for percussion mechanism. The insulated firing-pin (24) consists of four parts, the two inner ones screwed together at the joint of the case, and the two outer ones separated from the inner ones by spiral springs (25) which press them against primer and attachment-lug.

18. *The attachment-lug* (29) is another steel case fitting into a dovetail in the left side of the hinge-plate, and held there by a spring catch (30). An insulated circuit, with a contact piece (33) at one end and a spring-socket (34) at the other, extends through it.

19. The operation of the electric-firing mechanism is as follows: When the breechblock is pushed home the point of the firing-pin (24) is pressed against the electric primer in the base of the cartridge case, and when the block is turned and locked, the other end of the firing-pin comes opposite and is pressed against the contact piece (33) of the attachment-lug, thereby giving an insulated metallic connection from the electric primer to the spring-socket (34).

20. *One pole of the electric battery* is permanently connected to the metal of the mount, and the other pole is connected by an insulated wire passing through the firing-key to the spring-socket (34). Consequently, all connections being made, closing the firing-key ignites the primer. The wire from the firing-key ends in a metal cone which fits the spring-socket (34), and this wire may be of a length such that the recoil of the gun breaks the connection at that point. It is evident, however, that in no case can the gun be fired electrically until the breechblock is completely locked, because until then the firing-pin is not in contact with

the attachment-lug. If a blow-back from the primer occurs, the escaping gas forces the firing-pin (24) back slightly, when the head of the pin seals the front end of the firing-case (23) and prevents injury to the insulation.

21. It will be noted that, in the device described above, the firing-point always projects through the block and is liable to injury, by being struck by the cartridge case in loading, etc. A recent modification by Lieut. Graeme is arranged to keep the point housed within the breechblock and to press it forward, against the primer, in the last motion of closing the breech.

22. The percussion-firing mechanism (Plate II), designed to fit the firing-pin recess of the block, is, like that of the Dashiell system, of the type in which the firing-pin is drawn to the rear while opening the breech and the firing-spring compressed as the breechblock is locked, during closing. The principal parts are: The firing-pin and spring, the cocking-bar, the sear-bar and spring, and the trigger-box and trigger. The firing-pin (44) has a conical head ending in the firing-point (47); on its rear end is screwed a head (45) with a cannelure in which the sear is caught. The firing-spring (46) surrounds the firing-pin between its head and the cocking-bar (43). The latter, a nearly straight bar of steel, works back and forth on the firing-pin in slots cut through the plug; its extremities are rounded to fit the cammed grooves (68) of the carrier-ring. The sear-bar (49), bearing the sear (49a), is dovetailed in across the horizontal diameter of the block, closed position, and the sear-spring (51) forces this sear toward the firing-pin and the sear-bar toward the trigger (63). The trigger-box (62) is of the same shape as the attachment-lug of the electric mechanism and is secured to the gun in the same way; it contains the trigger pivoted at (64); the spring (65) forces the trigger in a direction opposite to that in which the lanyard, attached to the outer end, acts.

23. *The operation,* assuming the mechanism cocked for firing, is as follows: When the lanyard is pulled, the sear is forced to the right by the trigger until the firing-pin is freed; it flies forward from the force of the firing-spring and the gun is fired. As the breechblock is unlocked by turning to the right, the cocking-bar also rotates, its ends move along the grooves (68) in the

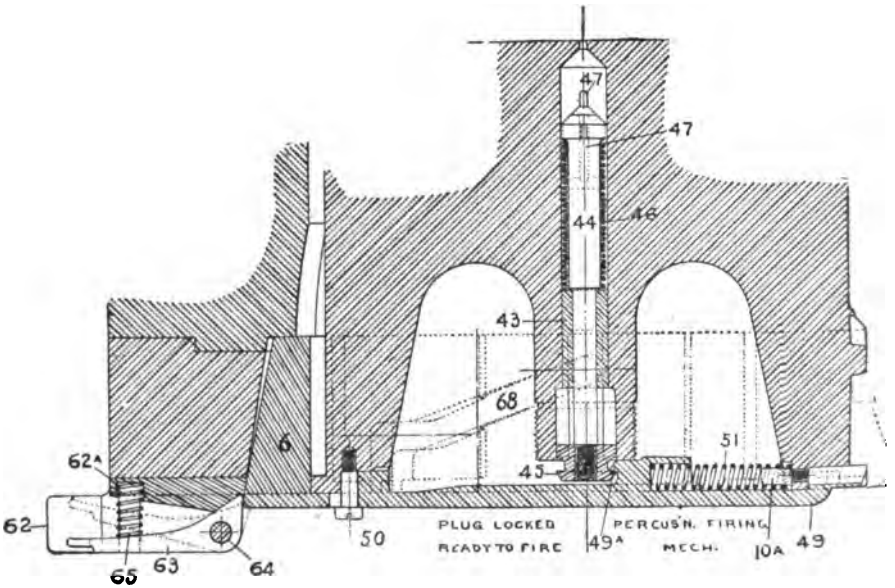


FIG. 1. Horizontal section.

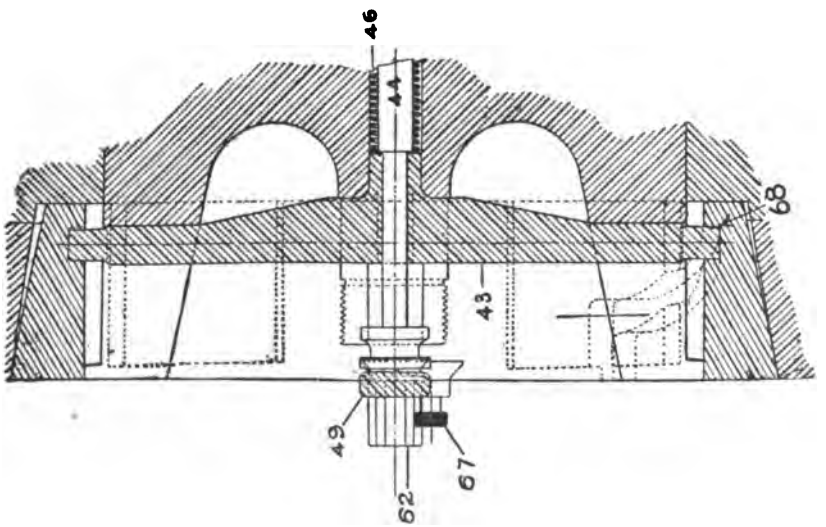


FIG. 2. Plug locked ready to fire.
Vertical section.

SECTION ON A.B.

THE FLETCHER BRE

THE FIRING

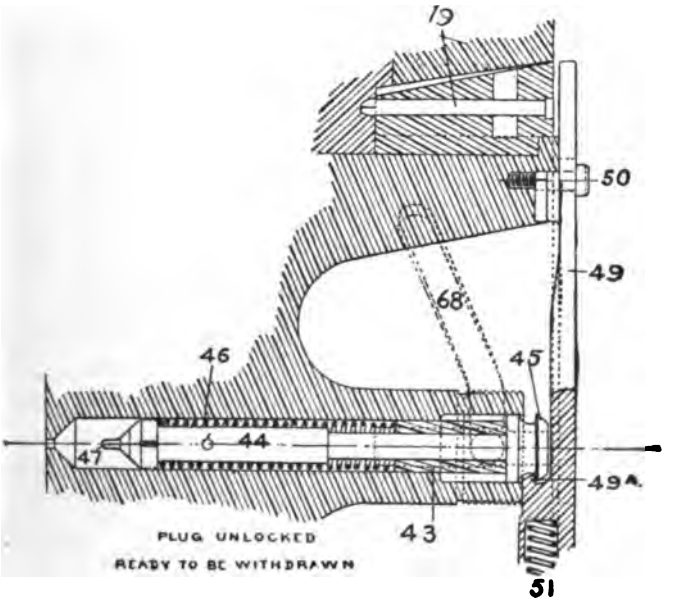


FIG. 2.

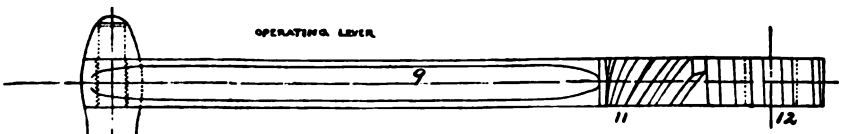


FIG. 4.

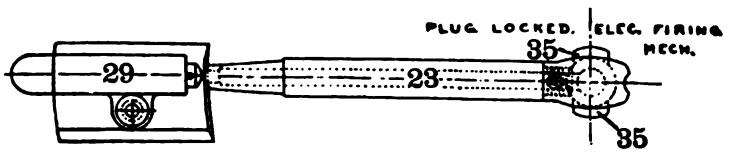


FIG. 5.

EECH MECHANISM.

MECHANISM.

carrier-ring, and it is brought to the rear with the firing-pin; at the moment that the unlocking of the block is completed, the firing-pin reaches the limit of its rearward motion and the sear snaps over its head. Then as the translation of the block begins, the ends of the cocking-bar emerge from the grooves (68) and the mechanism is retained in this position of full-cock, firing-spring slack, until the last step in closing. During the relocking of the block, the cocking-bar is forced *forward* by the grooves (68), which it has re-entered, and, the firing-pin being held to the rear by the sear, the firing-spring is compressed. Finally, just as the locking motion is completed, the left end of the sear-bar is brought into contact with the trigger and the gun is again ready for firing.

24. The gun cannot be fired prematurely by percussion, because: (1) The firing-pin, having been retracted during the opening of the block, cannot project through and strike the primer while closing unless—through weakness of the sear-spring—the sear has failed to grasp and hold the head of the firing-pin and even in that case a strong blow of its point upon the primer is unlikely since the cocking-bar limits the throw. (2) The firing-spring is not compressed until the block is at least partially locked. (3) The carrier-ring will not permit the sear-bar a movement to the right sufficient to release the firing-pin until the block is completely locked. The danger of exploding a percussion primer by the mere concussion of the breechblock against the cartridge case, while closing the breech, exists in this as in all other swinging-block systems.

25. The firing-point may be examined while the breech is open by pushing the sear-bar down and the cocking-bar forward, whereupon the firing-point will be projected through the face of the block; the sear must be re-engaged on the firing-pin head before closing or the mechanism will not be cocked.

CHAPTER IX.

BREECH MECHANISMS FOR 3-INCH AND 4-INCH R. F. GUNS.

4-inch Mechanism.

1. The 4-inch Mark VI breech mechanism is of service design, embodying the Welin stepped-screw principle and a modification of the Fletcher operating gear (it is sometimes called the "Modified Fletcher" mechanism), and is fitted to the 50-caliber 4-inch rapid-firing guns, Mark VII, from No. 213 upward, which are the only *main-battery* rapid-firing guns building.

2. It embodies the following characteristics:

(1) A Welin, or stepped-thread breechblock.

(2) The block is carried by threads on a "carrier-ring" hinged to the gun and swings directly out from the breech, without any movement of translation.

(3) *The operation of locking* or unlocking is performed by means of a spiral rack on the side of the block and corresponding teeth on a segment of the hand-lever hinged to the "carrier-ring."

(4) *The firing mechanism* is similar to the percussion device for the 4-inch or 5-inch Fletcher breech mechanism, but the firing-pin, being insulated, is also used for electric firing,—by a simple connection with an electric-firing cable and throwing out a "percussion-catch piece" on the "sear-bar."

(5) *The extractor* is carried in a longitudinal recess in the block itself, as in the Dashiell system, and its engagement with the head of the cartridge case is effected by a separate lip-piece with a transverse movement.

(6) *The screw-box* is cut in a breech-ring which screws into the jacket, abuts against the tube and is secured by set-screws.

3. The breechblock (Plate I), 6 $\frac{1}{2}$ inches total length, has 4 $\frac{1}{2}$ inches of its forward part divided into six equal sections;

each semicircle having a blank (2) and two stepped-threaded (3) sections. The blanks are diametrically opposite on the left and right sides, centers in horizontal axial plane, in the closed position. The stepped sections have radii of 4 and 4½ inches, the higher diametrically opposite to the lower, and the lower step being to the right of the blanks (going with the sun and viewed from the rear); these threaded sections are separated ⅛ inch for convenience in manufacture. The blanks, and upper part of teeth of first step, are cut concavely and convexly, with the hinge-pin as a center, to form clearances for swinging the block in and out of the screw-box. The nose of the block is recessed (4) to the rear to form a clearance for the head of the cartridge case, the flange being left thereon, for strength, as a continuation of the plug threads; the right side of the recess is sloped away somewhat to avoid jamming the case, if it is not pushed home.

4. The rear end of the block is left cylindrical for 1¾ inches on a diameter of 8¾ inches, and has a square left-hand thread (7) of ½ inch pitch (same as plug thread) cut thereon for attaching to the carrier-ring, except in that part where the unlocking-teeth are situated. In the ENE. side of the locked position, over an arc of 60 degrees, are cut five involuted teeth inclined 45 degrees to the horizontal which form a plug-rack (13) or unlocking-teeth, and are engaged by those on the hand-lever.

5. The rear end of the block is hollowed out for lightness and has an axial stem (9). Through this stem and the plug's axis is drilled a hole (10) for the firing-pin, conical in shape at the front end and diminishing to size of the firing-point. That part of the recess in which the "cocking-bar" works is enlarged, leaving a shoulder (11) there. Two vent holes (17), ¼ inch diameter, leading into the front end of the firing-pin hole and extending outward into the plug-recess, provide a means for the escape of gas in case of a blow-back.

6. A slot (12) is cut through the block in the vertical axial plane for a short distance, forming a way for the "cocking-bar." In the NNE. part (in the locked position) is cut a longitudinal extractor-hole (14) inclined 15 degrees to the axis and to the front, at the front end of which is cut a transverse clearance (15) for the extractor-head. In the rim of the block are cut dovetail slots (18)

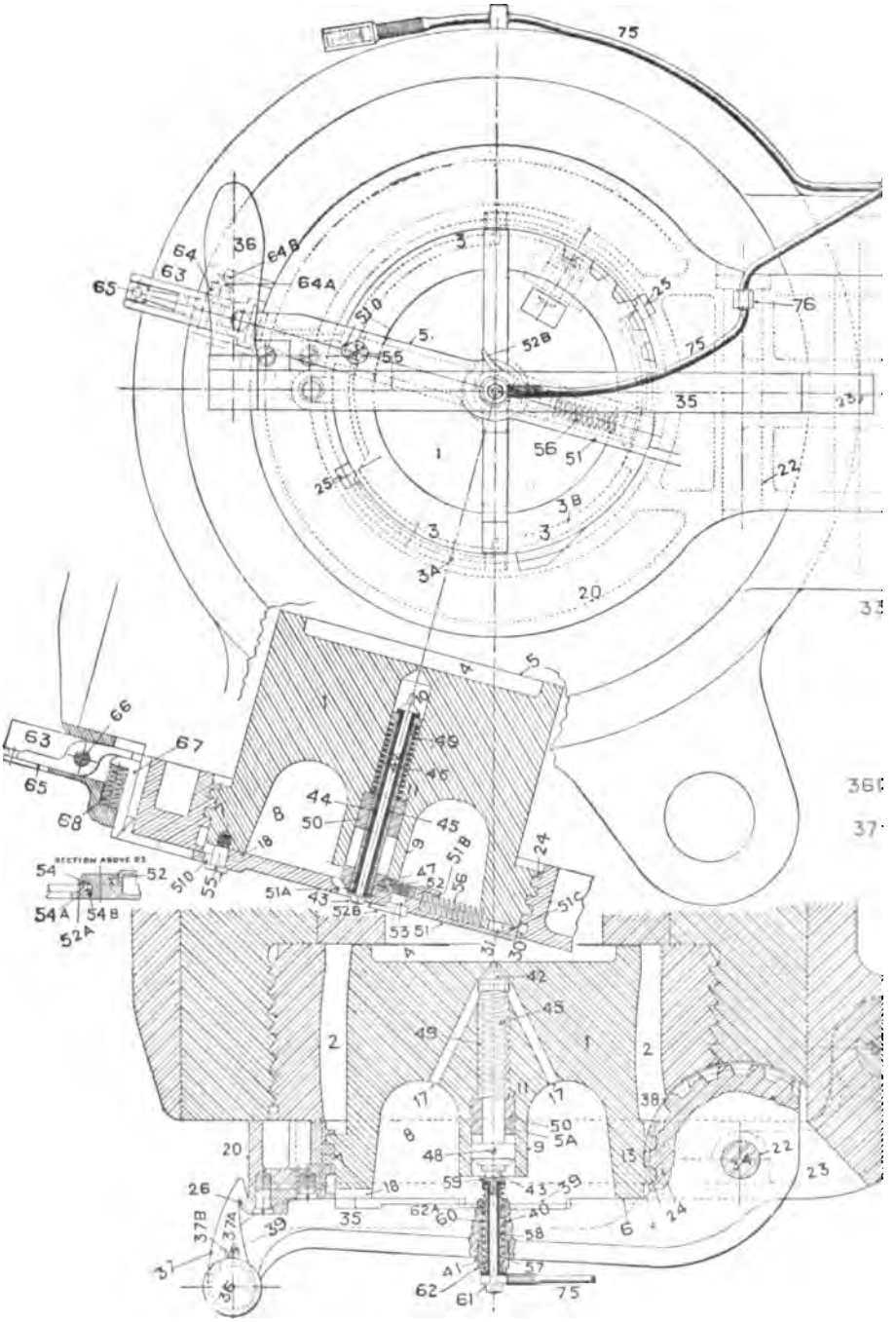
for the sear-bar lug, inclined 15 degrees to the horizontal. On the left side there is a cut in the thread of the carrier-ring, forming a recess (19) for the toe of the locking-plunger.

7. The carrier-ring (20) is designed to carry the breechblock and hand-lever. It is a circular cast-steel ring, suitably hollowed out in the front side for lightness, sloped off into an arm on one side which curves to the front and has a vertical hinge-pin hole (21), the center 10 inches from the center of the ring. The right end of the arm fits between hinge-lugs on the right side of the gun, and the hinge-pin (33), passing through the hole in the arm and hinge-lugs, secures the carrier to the gun. A boss is so cut on the arm as to leave a shoulder (32), which brings up on the yoke, limiting the extent to which the block is opened, viz., at right angles to the gun's axis. A slot (23), center in horizontal axial plane, is cut through the ring, and a vertical hole (22) passing through its arm is for the operating-lever pin (34).

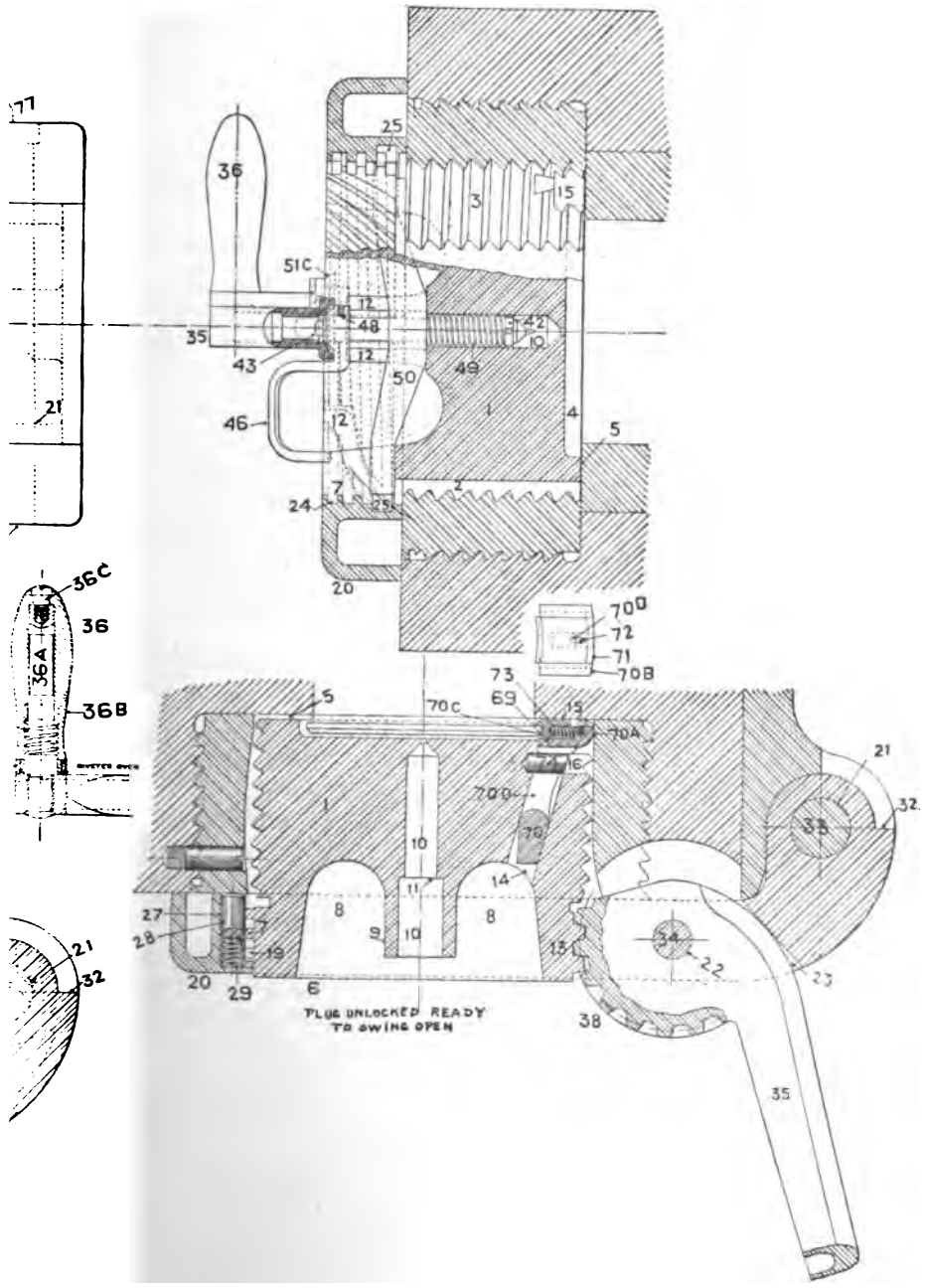
8. The inner surface of the ring has cut therein a square left-hand thread (24), into which screws the corresponding thread of the block. A cam-groove (25) for the cocking-bar is cut within the ring, across the threads, on diametrically opposite sides, opening at points 60 degrees to the right of the vertical line. There is a recess (27) for the locking-bolt (28). One-half inch above the horizontal axial plane, on the left side, is secured the "hand-lever catch piece" (26). At (30) and (31) are clearance-cuts for the sear-bar, for firing and cocking, respectively.

9. The operating lever (35) is a flat bar, provided with a vertical handle (36) on the left end, and a segment of a circle on the right, in which is a hole for the lever-pin which pivots it to the carrier-ring. On the front and inner surface (in closed position) are cut eight 45-degree teeth (38), which engage the block's rack teeth (13) and by which it is rotated to lock or unlock. The front edge of the bar is cut out (39) to clear the sear-bar when closed and is scored for lightness; near the center, the lever has its full width and a longitudinal hole (40) is drilled for the "electric contact-sleeve."

10. *The handle* (36) consists of a stud (36a) screwed into the left end of the lever, over which works a sleeve (36b). The lower end of the sleeve is screwed into a lever-catch (37), which sur-



4-INCH BREECH ME



CHANISM, MARK VI.

rounds the stud next to the lever. A helical spring (36d), with one end fitting into a groove in the sleeve and the other in the stud, always tends to revolve the lever-catch to the right. The end of this catch is provided with a hook, which will engage the lever-catch piece on the carrier when the hand-lever is fully closed. A small limiting-slot (37a) in the catch and a pin-screw stud (37b) screwing into the lever prevent undue revolution of the lever-catch.

11. The firing mechanism consists principally of an insulated firing-pin, firing-pin sleeve, cocking-handle, firing-pin spring, a cocking-bar, sear-bar, trigger mechanism, and electric-contact connections. The firing-pin (42) is a straight circular rod with the usual conical head and point, threaded at the rear end for a nut (43), and is surrounded by a vulcanite bush (44) and a vulcanite washer against the head and in front of the nut. A steel sleeve (45), with a collar at the front end and threaded at the rear end, surrounds the insulation and lies between the two insulating washers; this sleeve, with the insulation, is kept in place by the nut (43) screwed on the rear end of the firing-pin.

12. *A cocking-handle* (46) is screwed on the rear end of the sleeve and is retained there by a set-screw (48). On the right side of the handle's hub (in the assembled position) is a cock-notch (47) for the sear-bar. The end of this handle works in the lower cut for the cocking-bar in the plug's rim and acts as a guide to keep the cock-notch in the proper position. The (spiral) *firing-spring* (49) surrounds the sleeve and lies between the collar on the latter and the cocking-bar.

13. *The cocking-bar* (50) is quite similar to that of the 4-inch and 5-inch Fletcher mechanism; it works over the firing-pin sleeve, forward of the cocking-handle, and its ends take in the cocking-grooves (25) in the carrier-ring. The insulated firing-pin, sleeve, firing-spring, cocking-bar, and cocking-handle are assembled as *one piece,* as in the 4-inch or 5-inch Fletcher mechanism, the spring being under a slight initial compression.

14. *The sear-spring* (56) and *sear-bar* (51) are very similar to those of the 4-inch and 5-inch Fletcher mechanism, and work in the same way. There is an oblong hole (51a) near the center of the bar through which the rear end of the firing-pin sleeve passes;

it is hollowed out to clear the hub of the cocking-handle. There is a separate piece on the front side of the bar to right of the hole, to form a " cocking-catch " (52) or lip for percussion-firing, which is retained and pivoted on the bar by a screw (53). This catch may be turned up 90 degrees (by turning it with the finger) so that the cock-notch of the firing-pin will not be engaged, when it is desired to use the electric-firing mechanism. To keep this cocking-catch piece in either position, there is provided a lock (54) consisting of a small spring-plunger (54a) seating in a hole on the front side of the bar, and worked by a spring (54b) ; this plunger will enter a recess in the cocking-catch in the two 90-degree positions. The left end of the sear-bar, when the block is closed, slides behind a lip on the lever-catch piece (26), and prevents rear displacement by the trigger-bar; the left edge of the bar is beveled for the sliding trigger-bar.

15. *The trigger mechanism* consists of a box (63) held in a dovetail groove cut in the gun on the left side, on a line 15 degrees above the horizontal by a spring bolt (64a) entering the recess. A " trigger-lever " (65) is pivoted near its middle within the box, its inner end bearing on the foot of the trigger-bar (67), which slides fore-and-aft in a dovetail groove, and has a foot against which bears a spiral spring (68), seated in a recess in the box, tending to keep it in its forward position; on the after end of the trigger-bar is a beveled surface. When the outer end of the trigger-lever is pulled forward, the bar is moved aft, and its beveled surface bearing on the sear-bar moves the latter to the right far enough to disengage the firing-pin.

16. *The electric-firing wire* is connected to a contact-piece, so carried in the operating lever that it will lie in the axis of the bore when the breech is closed. The wire is secured to the rear end of the contact-piece (59) which is held in an insulated sleeve (58) ; this sleeve is capable of considerable longitudinal motion against the action of a spring (60). The spring will, when the firing-pin is not cocked, press the contact-piece against its head, completing the electric circuit; when cocked for percussion firing, the spring yields enough to permit the lever to close. Thus the same firing mechanism is used both for percussion and electric firing and the gun may be fired by either means without dismounting anything. Combination primers are used.

17. The extractor (69) consists of a lever (70) or tail, lip-piece (71) and screw (72), spiral spring (73) and retaining-pin. The front end of extractor has a double-lipped guide-slot for the lip-piece (71) at right angles to the tail. The tail of the extractor works within the inclined hole (14) in the block, which keeps the extractor in the block. A lip-piece, sliding in the lipped-groove on the front end of the extractor-tail, has a small right and left movement, and is retained by a screw-pin (72) through an oblong hole. A spiral spring (73) is placed in a recess on the underside of the lip-piece and bearing on the end of the groove. The extractor tends always to keep the lip-piece engaged under the rim of the case. A longitudinal slot (70d) is cut in the tail, through which passes a pin (74) at the front end of the extractor-hole and enters a recess in the block.

The Action of the Breech Mechanism.

18. To open (supposing the breech closed).—Grasp the handle of the operating lever, turn it to the left to disengage the lever-catch from the carrier, then pull to the rear. The spiral threads on the lever engaging those of the rack will rotate the block to the right to unlock. While the block is being unlocked, the ends of the cocking-bar working in the grooves of the carrier-ring will move the bar to the rear, and with it the firing-pin, until the cock-notch is engaged by the catch on the sear-bar. The latter is able to move to the right sufficiently to allow the lip of the catch to ride up the bevel of the notch by means of the cocking-clearance (31) in the ring. At the moment the block is unlocked, the upper end of the square threads for the carrier will bring up on the top of the lever-segment and stop the rotation, and the lever, block, and carrier will then swing out together on the hinge-pin as an axis. As soon as the carrier clears the breech-face, the locking-plunger (28) springs forward and its toe enters the cut (19) in the block, preventing any movement of rotation of the latter within the ring when the direction of the lever's movement is reversed. As the block swings out from the screw-box, the extractor's tail, working in the inclined hole in the block, will cause the extractor to move about its fulcrum, bearing on the side of screw-box, throwing the

inner end of the lip-piece to the rear and prying out the case with great power. As soon as the block has traveled to the rear the length of the slot in the extractor-lever, the extractor brings up on its keep-pin (74) and the block and extractor move in unison to the rear, withdrawing the case until the lip-piece slips off the rim of the cartridge case. When the lever has swung about 190 degrees, the shoulder (32) on the carrier brings up on the hinge-yoke and stops the movement. The rear face of the block is then parallel to the axis of the bore.

19. To close.—The movement of the lever is the reverse. When the locking-plunger (28) in the carrier-ring strikes the breech, its toe moves to the rear and releases the block, and as soon as the carrier strikes the breech face of the gun, the center of movement of the lever is transferred from the hinge-pin to the lever-pin, and the spiral teeth of the lever rotate the block to the left, locking it into the screw-box. During the block's rotation, the cocking-bar is moved forward by the grooves (25) in the ring and, the firing-pin being held by the sear-bar, the firing-pin spring is compressed. When the block is fully locked, the operating lever is latched to the carrier by the catch (37) engaging that on the carrier, and the left end of the sear-bar is in contact with the trigger-bar. To change from percussion to electric firing when the firing-pin (42) is cocked, *without opening the breech,* first pull the cocking-handle (46) a short distance to the rear to release the cocking-catch piece (52) from the safety-notch (52a) so as to clear the cock-notch on firing-pin, then allow the firing-pin to go forward slowly. If it had been intended in the first place to fire by electricity, the cocking-catch should have been pushed to the right before closing the breech; then the sear-bar would not have held the firing-pin and it would have been merely pushed against the primer by the cocking-bar without compressing the mainspring. Now if it be desired to change to percussion firing, without opening the breech, it is only necessary to push the cocking-catch over to the left, grasp the cocking-handle and pull it to the rear, compressing the firing-spring, until the sear-bar snaps over the firing-pin head. Obviously there can be no electric connection to the primer when cocked for percussion firing, and when the firing-pin *is* forward in contact with the primer the mainspring is not compressed.

20. *The electric contact-piece* (59) in the lever should always remain in the same place, as it requires no adjustment when changing from percussion to electric firing.

21. To fire.—If the percussion mechanism is used, pull on the lanyard attached to the outer end of the trigger-lever. The trigger-bar will move to the rear, and its beveled surface will move the sear-bar to the right sufficiently to disengage the firing-pin, which will fly forward under the action of the compressed spring and strike the cap of primer.

22. Points of safety.—The gun cannot be fired before the block is fully locked; first, because the sear-bar cannot move to the right to disengage the firing-pin until the firing-clearance (30) in the carrier-ring is reached, except in the unlocked position when there is no compression on the firing-spring; second, if the electric mechanism is used, there is no contact between firing-pin and primer or between contact-piece and firing-pin until the operating lever is fully closed.

23. The block will not unlock on firing; first, because the position of the lever is beyond the center of movement to the rear; second, the hand-lever catch prevents the movement of the lever which is necessary if the block rotates.

24. The firing mechanism will not be injured if an escape of gas occurs, as gas vent-holes (17) are provided in the block to relieve the firing-pin.

3-INCH R. F. BREECH MECHANISMS.

25. There are now (1904) in service or under construction 261 3-inch R. F. guns; at the time of writing it is intended in the future to build all 3-inch guns on some semi-automatic principle. While 3-inch guns are properly designated as secondary-battery guns, their breech mechanisms are more like those of the main battery. Mark I 3-inch mechanism is a Fletcher mechanism fitted to the field pieces. Mark II has a system of operation somewhat resembling the Dashiell system and is fitted to 100 3-inch 50-caliber guns built by the American Ordnance Company. Mark III has a modified Fletcher operating gear similar to the 4-inch mechanism described above and is fitted to 161 50-caliber 3-inch guns. All 3-inch guns are fired only by percussion.

3-inch B. M. Mark III.

26. The Mark III mechanism (see Plate II) is similar to the 4-inch mechanism just described but differs principally as follows: (a) The breechblock is of the ordinary or unstepped type; (b) the block, instead of being held inside the carrier, is screwed *over* a boss projecting from its surface, in which the cocking-bar works in the same manner; (c) opening or closing is likewise accomplished in two motions, *rotation* and *swinging*—(portions of the block and screw-box being sloped away to permit it), but the operating lever is pivoted on the carrier hinge-pin and only one center is used; (d) the hinge-pin, trigger-box, etc., are held by a hinge-plate (A) bolted to the breech of the gun; (e) the extractor is like that of the ordinary Fletcher mechanism.

27. The breechblock (1) is chased with a left-hand abutment-thread, divided into six equal sections, three of which are planed out to form blanks (3). The threaded sections (2) are on the left, upper-right, and lower-right quadrants in the closed position. The left blank of the block and the two left blanks in the screw-box are cut away to form a clearance (4) for swinging out on the hinge-pin (25) as a center. The rear part is hollowed out axially to form a cylindrical recess (11), the bore of which is chased with a square left-hand thread of the same pitch as the plug-thread; the boss of the carrier-plate screws into this thread (19). On the right side of the rear face of the block is bolted a separate segment covering 60 degrees of arc, on the surface of which is cut a rack of teeth inclined 45 degrees, forming the rotating-segment (14) and rotating-teeth (14a); diametrically opposite is cut a circular groove, center in axis of block, called the safety-groove (9) in which enters the safety-toe (41b) of the sear-bar to prevent firing the gun in any but the fully closed position of the breechblock. This is accomplished by having the groove run in radially to the recess in the block only at the two ends of said groove. A recess for the locking-plunger (10) is provided on the left side of the rear face, so that when the block is rotated to the unlocked position, the locking-plunger (22), carried by the carrier-plate, springs in and secures the block from any rotation during the "swing" out or in, with the carrier (15), on the hinge-pin (25). The axial

firing-pin hole (13) and stem (12) are similar to the Fletcher type.

28. The carrier (15) is a flat circular plate having two jaws on the right side containing the hinge-pin hole; it is hinged by the pin (25) to the hinge-plate (A), the slot (17) between the jaws being for the operating lever. On the forward side in its center is a cylindrical boss (19) having cut thereon a square left-hand thread, of plug-thread pitch, on which is screwed the breech-block. The boss is hollow and has cut in its inner surface two diametrically opposite cocking-cam grooves (20) for operating the cocking-bar (40) of the firing mechanism (similar to the Fletcher 5-inch). In the horizontal center-line a slot (18) is cut through, partly dovetailed at the right and left ends, in which works the sear-bar (41), and on the right side is formed a seating for the sear-spring as per figure. On the rear face, left side, just above the sear-bar, is a catch (24) for the operating lever's latch. On the forward side, opposite to the upper end of the left screw-box thread, is a recess containing a locking-plunger (22) within which is a spiral spring (23) which operates the former, so that when the block is unlocked and the carrier swings from the breech-face, the plunger (22) is forced into the recess (10) in the block.

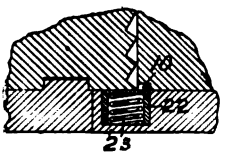
29. The operating lever (26), working on the (carrier) hinge-pin (25) within the jaws of the carrier, is provided with a segment (30) on the right inner side of which are cut a number of 45-degree teeth (30a) to engage those of the rotating-segment (14) on the block, and by which the block is locked or unlocked. The back of the lever at its right end forms a cam surface (28) for operating the extractor (35) as in the case of the Fletcher breech mechanism; underneath this surface is worked, solid with the lever, a lug (29), which, bringing up on the outer surface of the gun when the breech is opened, acts as a stop and prevents a blow on the extractor-pin. On the left end of the lever is a handle (31) or hand-grasp: the handle is provided with a (bell-crank) lever-latch (32) pivoted at the bend, which snaps over the catch (24) on the carrier when the breech is fully closed, through the action of the spiral spring (33) and plunger (34), as per figure. This prevents the breech from opening at any elevation.

shock of the charge, or accident, and therefore must be deliberately freed by pressure of the hand when it is desired to open the breech.

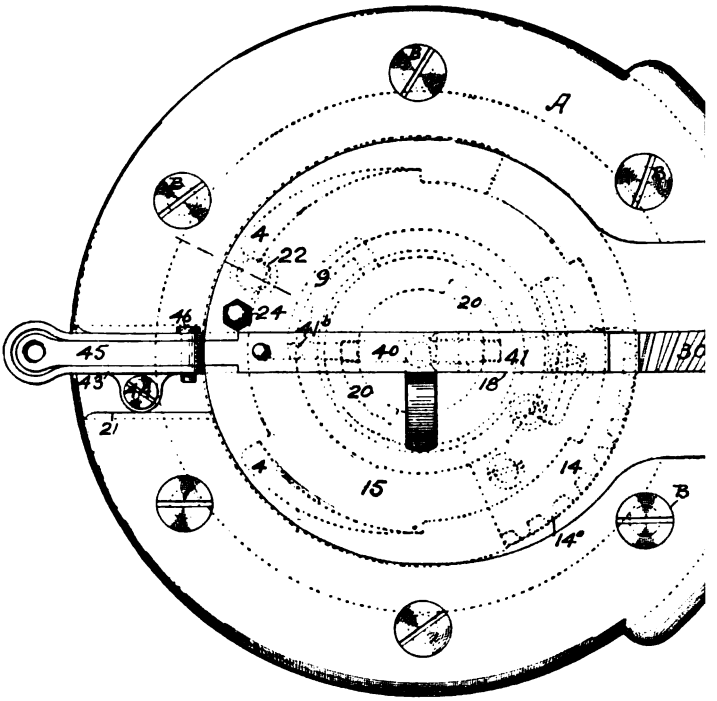
30. The extractor (35) is similar to the Fletcher, though somewhat more bent, and is placed and operated in a similar manner.

31. The firing mechanism—percussion firing is exclusively used—consists of firing-pin, firing-spring, cocking-bar, cocking-handle, sear-bar with sear and sear-spring, and trigger-box, and is very similar to that of the 4-inch Mark VI mechanism. The firing-pin has the usual conical head (37) and on its rear end is screwed a nut (38) which is provided with a cock-notch and a cocking-handle (38a), extending to the rear through a guide-slot in the carrier, which prevents its turning. The firing-spring (39) surrounds the firing-pin between its head and the cocking-bar (40) which lies in a slot through the stem (12) by which it is forced to rotate with the block; its ends engage the cam-grooves (20). The firing-pin may be eased down from the position of full-cock, when the breech is closed, by the cocking-handle or the mechanism may be recocked by it, without opening the breech. The sear-bar (41) slides to the right and left, against its spring (42), within a slot in the *carrier* and its only connection with the block is by the safety-toe (41b); the sear (41c) engages the firing-pin when cocked and releases it when the trigger presses the bar to the right. The safety-toe is a projection on the left forward side of the sear-bar which works in the safety-groove (9) of the block in such a manner that the sear-bar can be forced to the right, only in the fully closed position, to permit firing and, in the unlocked position, to permit the sear to snap into the cock-notch of the firing pin. The trigger mechanism is quite similar to that of the 5-inch Mark II breech mechanism (Fletcher No. 2) except that the trigger-box (43) is secured by a screw (44) instead of a spring catch.

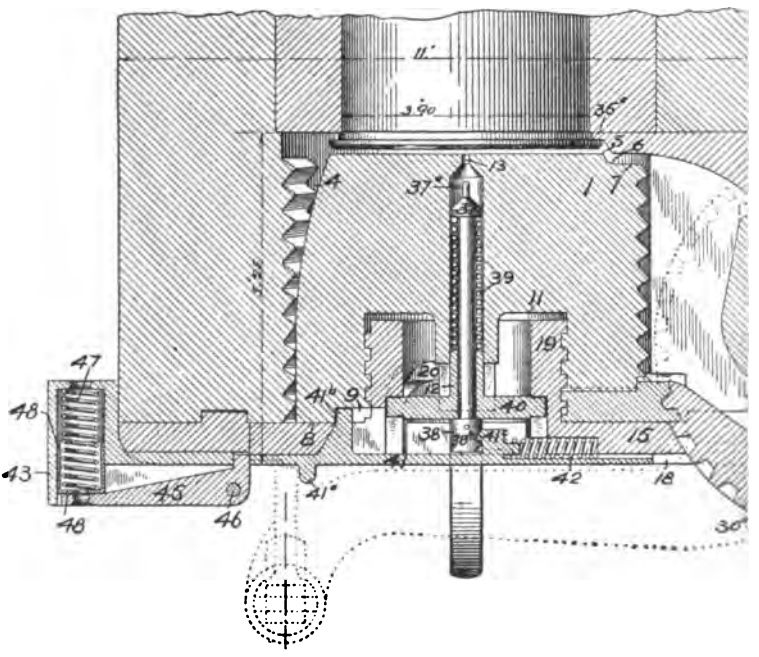
32. The operation of the breech mechanism is as follows: The breech being closed, *to open*, grasp the handle of the operating lever, compressing the upper arm of the lever-latch to release the same from the catch on the carrier, then swing smartly to the right until the stop (29) brings up on the right side of the gun. When the lever has swung 61 degrees the rotating-teeth have re-



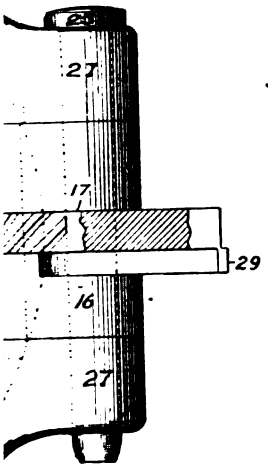
Locking Plunger.

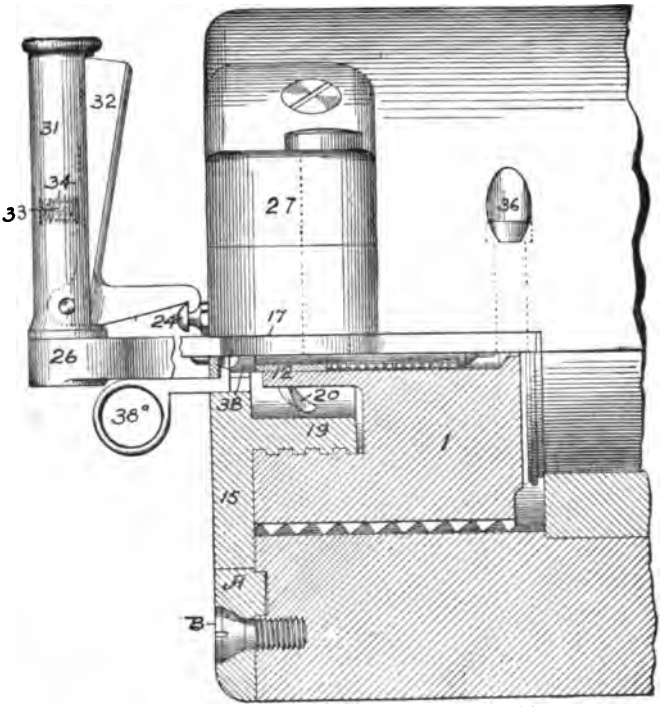


PLUG UNLOCKED

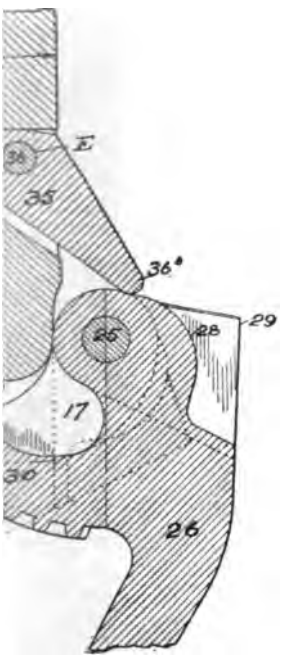


3-INCH BREECH MEC

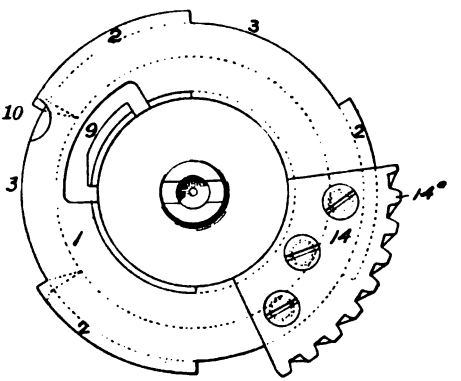




PLUG LOCKED



HANISM, MARK III.



volved the block to the unlocked position, the rotation being stopped by the lower edge of the block's rotating-segment striking the end of the circular cut in the screw-box, provided as a clearance for it; the locking plunger is now directly in line with the recess in the block. During the rotation the cocking-bar is brought to the rear through the action of the cam-grooves (20), as it is forced to turn with the block by reason of the guide-slots on the block-stem, and with the cocking-bar comes the firing-pin until the cock-notch (38b) engages the nib (41c) of the sear. The further swing of the lever of 100 degrees swings the carrier and block out from and clear of the screw-box, and the moment the carrier leaves the face of the breech the locking-plunger springs into the recess (9) in the block, locking the latter from movement on the carrier-boss. The extraction takes place during the whole of the swinging movement, slowly at first, then more rapidly.

33. To close.—The reverse movement is given to the operating lever until the lever is folded across the breech and held by the latch. The locking-plunger releases the block the moment it strikes the face of the breech, permitting the block to revolve to the locked position; during the revolution the cocking-bar is moved forward, compressing the firing-pin spring (39). When the breech is fully closed, the block is locked in the screw-box, the lever is latched to the carrier, the left end of the sear-box is in line with the trigger, and the safety-toe (41b) is opposite one of the cuts in the safety-groove.

34. To fire.—On pulling the lanyard attached to the outer arm of the trigger the sear-bar is moved to the right, releasing the firing-pin, which flies forward under the action of its spring and strikes the primer of the cartridge case. The sear-spring returns the sear-bar to the original position. Should a missfire occur, the firing-pin may be recocked by pulling to the rear on the recocking-handle.

35. Safety.—(1) Premature discharge is impossible because the firing-spring is not compressed and the sear-bar cannot release the pin, until the breech is fully closed; (2) the breech will not open when the gun is elevated because of the hand-lever latch, nor can it be accidentally opened; (3) the breech will not open on

firing, because of the reverse action of the lever on recoil as well as the natural friction of the block and spiral threads.

The Mark II 3-inch Breech Mechanism.

36. The Mark II mechanism has but little similarity with that of other R. F. guns, but has an operating gear somewhat like that of the Dashiell system. (Plate III gives various complete and partial sections and Plate IV shows the entire mechanism dismounted.) It is to be noted that: (1) The block is secured to a boss on the carrier as in the Mark III mechanism, and after *rotation* also *swings* open on the carrier hinge-pin; (2) the extractor is not a part of the block; it is secured by the carrier hinge-pin, but does not swing on it as a center; (3) the cocking and the compression of the firing-spring are both accomplished during *opening.*

37. The principal parts of the mechanism are: the *breechblock* with rotating, locking, and stop-studs; the *carrier;* the *operating lever* and lock; the *extractor* and cam and the *firing mechanism,* (percussion firing only is employed).

38. The breechblock (10) has four threads and four blanks; the blanks are, when the block is locked, at top, bottom, and sides. The right and left blanks of the screw-box are curved as shown in order to permit *swinging* without *translation.* The breechblock is hollowed from the rear to receive the firing-case, and is provided with a suitable bayonet-joint in which the corresponding lugs on the firing-case lock. On the inner surface of the block is the cocking-cam (10 D) seen in projection Fig. 6, Plate III. On the rear face of the block-hub is the block safety-lug (10 E), seen in Fig. 5, Plate III, and in Plate IV. The threads on the block, seven in number, are blanked to correspond with the threads in the screw-box; the rear thread of all is left continuous and acts as a stop-thread. A small recess (10 H) is cut in this thread for the block-locking-bolt. The block-stop stud (10 B), and block-rotating stud (10 C), are screwed into the rear face of the block.

39. The hinge-plate (12) is secured to the right side of the gun by four large screws. The hinge-pin (17) passes through the carrier hinge-lugs (11 B), the hinge-plate lugs (12 A), the extractor (18), the extractor-cam (19), and the operating lever (16).

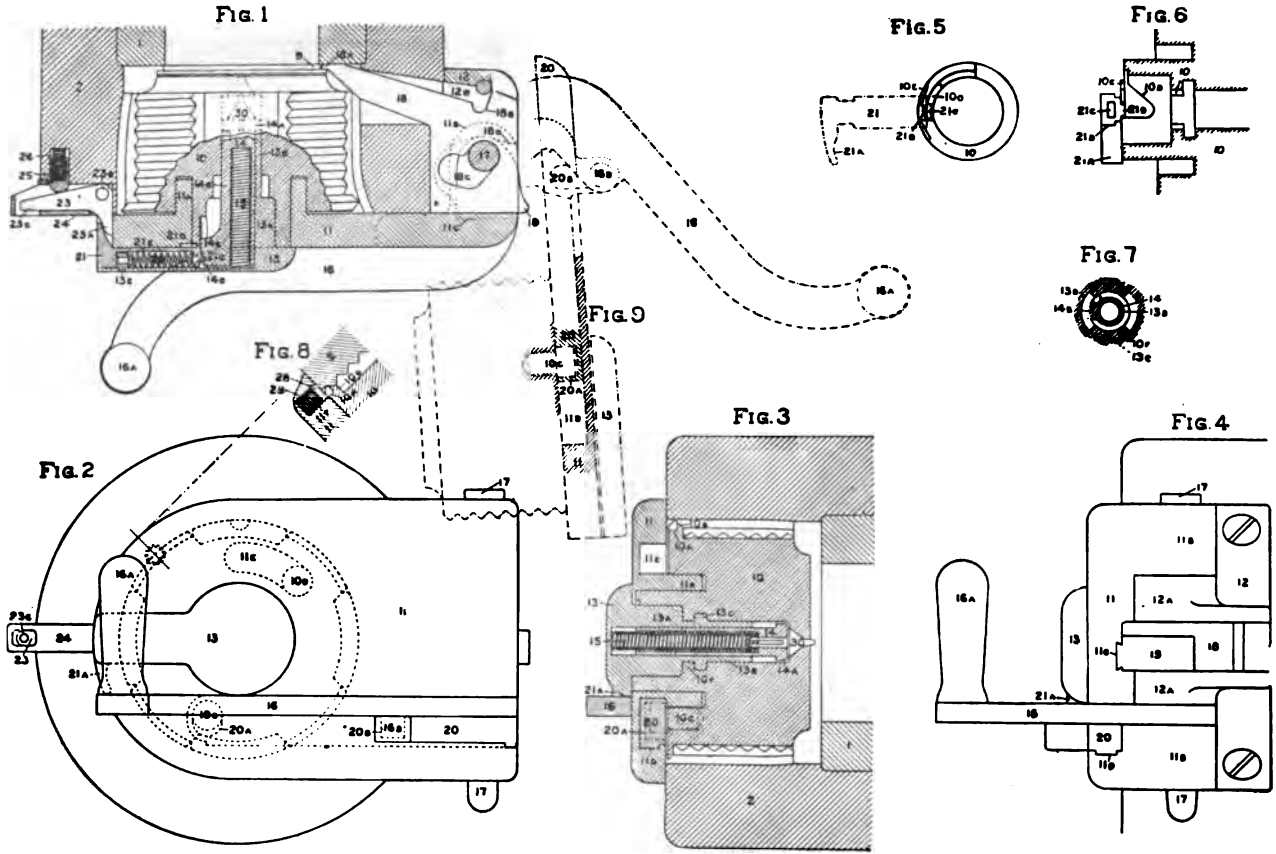


Fig. 1.—Horizontal section through center of breech of gun, and a partial section of the breechblock.
Fig. 2.—Rear elevation of breech.
Fig. 3.—Vertical longitudinal section through center of breechblock.
Fig. 4.—Side elevation of breech mechanism.
Fig. 5.—Outline sketch of rear elevation of sear and hub of breechblock.
Fig. 6.—Side elevation of same.
Fig. 7.—Vertical transverse section through bayonet lugs of firing case and through firing pin.
Fig. 8.—Longitudinal section through center of block-locking plunger. This section is inclined 45° from the vertical.
Fig. 9.—Breech open.

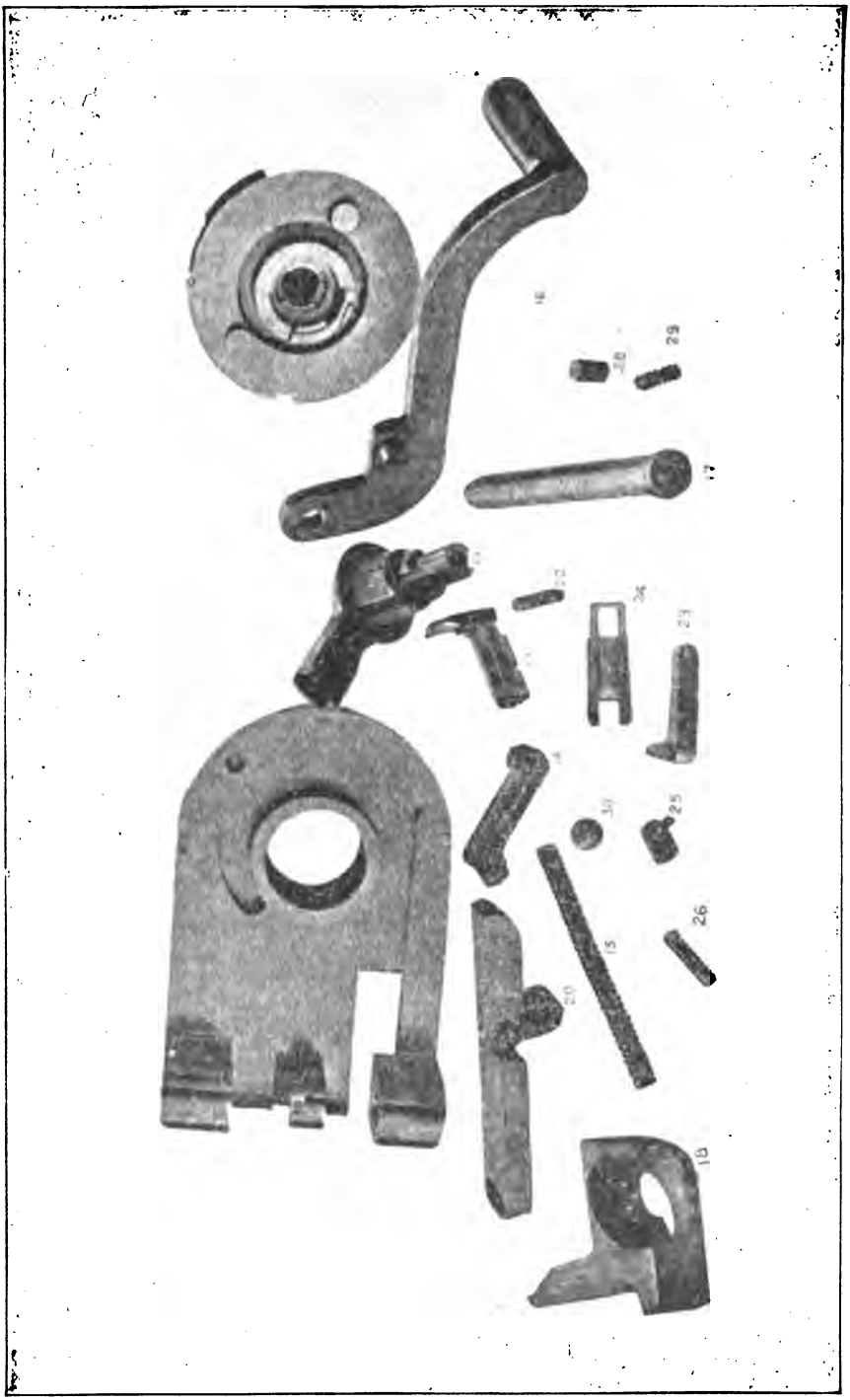
40. The carrier (11) has on its lower side a transverse horizontal recess (11 D), the rack-slot; above the rack-slot is the extractor cam-seat (11 C) (Fig. 4, Plate III). The carrier is bored through its rear face at a point concentric with the bore of the gun to receive the *breechblock-hub*, and has on its forward face a boss (11 A) which assembles in a corresponding annular recess in the rear face of the block. On the rear face of the carrier and to the left of the hole for the breechblock-hub is a shallow clearance-cut for the sear safety-lug; this cut is seen to the left of (21 D) (Fig. 1, Plate III). On the left side of the carrier is a longitudinal slot in which the toe of the sear rests (see Plate IV). On the forward face of the carrier is the block-stop slot (11 E) and in the upper left hand side, a seat in which rests the locking-bolt (11 F); this bolt, pressed forward by its spring, drops into a recess in the block as the unlocking is completed.

41. The operating lever (16) is a long arm, without a handle-locking device, pivoted on the hinge-pin in a slot in the lower part of the carrier; it has a stud (16 B) on its lower side which operates the rack. The rotating link (20) is attached to the breech-block by the stud (10 C) which works in a slot (20 A) in its left end by which, when the link is moved to the right or left, the block is rotated.

42. The firing-case does the double duty of containing and guiding the firing mechanism and of securing the block to the carrier. The head of the case is made large to give it a bearing on the carrier; it passes through the latter and, engaging the bayonet-joint of the block, locks the two firmly together. (Since there is no screw-thread action in this device the carrier will move up to or away from the gun as the block is rotated.)

43. The *firing-case* (13) is a stepped cylinder, hollowed out to receive the firing-pin (14) and the firing-spring (15). On its rear end it has a projecting lug which is slotted to receive the sear (21); the cylindrical portion is slotted for the firing-pin guide-rib. On the stem of the case are two bayonet-lugs which serve to lock it to the block; in the sear-slot there is a lug which furnishes a bearing for the outer end of the sear-spring (22).

44. The *firing-pin* (14) is a hollow cylinder, partially closed at its forward end and having a guide-rib (14 B); this guide-rib,



PARTS OF MARK II 3-INCH BREECH MECHANISM.

toward its rear end, projects into a lug on which are the cocking-lug (14 C) and the cock-notch (14 D). The firing-point (30) has a split shank and is assembled with the firing-pin by simply pushing the shank into the firing-pin head (14 A). The firing-spring (15) is spiral; its forward end abuts against the forward end of the cylindrical recess in the firing-pin, its after end abuts the after end of the firing-pin recess in the firing-case.

45. The sear (21) is shaped to travel in the sear-slot in the firing-case. It is hollowed out to receive the sear-spring (22), one end of which abuts against the lug in the firing-case, as before described, and the other end of which abuts against the inner end of the sear-spring recess in the sear. The sear-guide ribs (21 B) travel in corresponding ways in the firing-case, and prevent the displacement of the sear. On the inner forward side of the sear is the sear safety-lug (21 D) which, when the block is not completely closed, engages the block safety-lug (10 E) (Plate III, Fig. 5), and prevents the sear from being withdrawn far enough to release the firing-pin. The sear cock-notch (21 C), the sear-toe, which engages the trigger-toe (23 A), and the sear finger-catch are plainly shown in the plates. The firing-case is inserted at an angle of 90° to its final position, pushed in until the bayonet joint "takes" and then turned to the left until its toe snaps into the slot in the edge of the carrier.

46. The extractor (18) is best shown in Fig. 1, Plate III, and in Plate IV. The hinge-pin passes through the extractor guide-slot (18 C); the under side of the extractor, contiguous to the extractor guide-slot, is cut away to the extractor-cam surface (18 D). On the forward side of the extractor is the extractor pivot-groove (18 B). The *extractor*-cam (19) is shown in Plate IV assembled with the carrier; it is held in place by the hinge-pin which passes through it. It has no motion relative to the carrier, and its outer surface bears against the extractor-cam surface.

47. The operation of the mechanism is as follows: *To open:* The gun having been fired, the first movement of the operating lever causes the operating-lever stud (16 B) to press against the corresponding slot (20 B) in the rotating link and produce a movement to the right. The link being in engagement with the block-rotating stud, the block rotates until the block-stop stud

(10 B) brings up against the end of its slot (11 E), so that the block can rotate no farther; this rotation of the block is to the left and about the firing-case, which remains rigid with the carrier. The cocking-lug on the firing-pin lies, during the rotation of the block, against the cam on the inner surface of the block-hub. The rotation of the block, therefore, carries the firing-pin to the rear, compressing the firing-spring and camming out the sear until it engages the firing-pin cock-notch (14 D) (Fig. 1, Plate III). After the rotation of the block is arrested, the further movement to the right of the operating lever causes the carrier, and with it the block and firing-case, to swing clear of the breech.

48. As soon as the carrier leaves the breech, the locking-plunger (28) (Fig. 8, Plate III) springs into its recess and locks the block against rotary movement until the carrier is again swung to.

49. As the carrier revolves away from the breech of the gun, the extractor-cam, working on the cam surface of the extractor, causes the outer end of the latter to move forward. The extractor then acts with great leverage on the cartridge head, the fulcrum being the forward inner edge of the extractor-mortise (see Fig. 1, Plate III). The carrier swinging still farther to the right, the outer end of the extractor is pushed so far forward that its fulcrum shifts to the extractor-pivot (12 B). This results in less leverage and more velocity for the nib of the extractor; the final movement of the extractor-nib is its swiftest movement and results from the shape of the extractor-cam (19).

50. *To close:* The first movement of the operating lever to the left swings the carrier to until the stop-thread of the block brings up against the first thread of the screw-box. The locking-plunger at the same time strikes the edge of the screw-box and is forced to the rear, releasing the block. A further motion of the lever will now rotate the block until the block-stop stud reaches the other end of the slot and the block will be in its locked position with the sear engaged with the trigger. (The trigger and its box are similar to that of the Mark III mechanism except that the motion of the sear in firing is *outward.*)

51. Safety.—Premature firing is impossible because: (1) The block safety-lug (10 E) lies to the left of the sear safety-lug, pre-

venting release of the firing-pin by any cause, and the sear is not engaged with the trigger, until the block is locked. (2) If, through the breaking of the sear cock-notch, firing-pin cock-notch, or either of the safety-lugs, before the breech is fully closed, the firing-pin is released, the cocking-lug (14 C) will bring up on the cocking-cam (10 D) before the firing-point touches the primer.

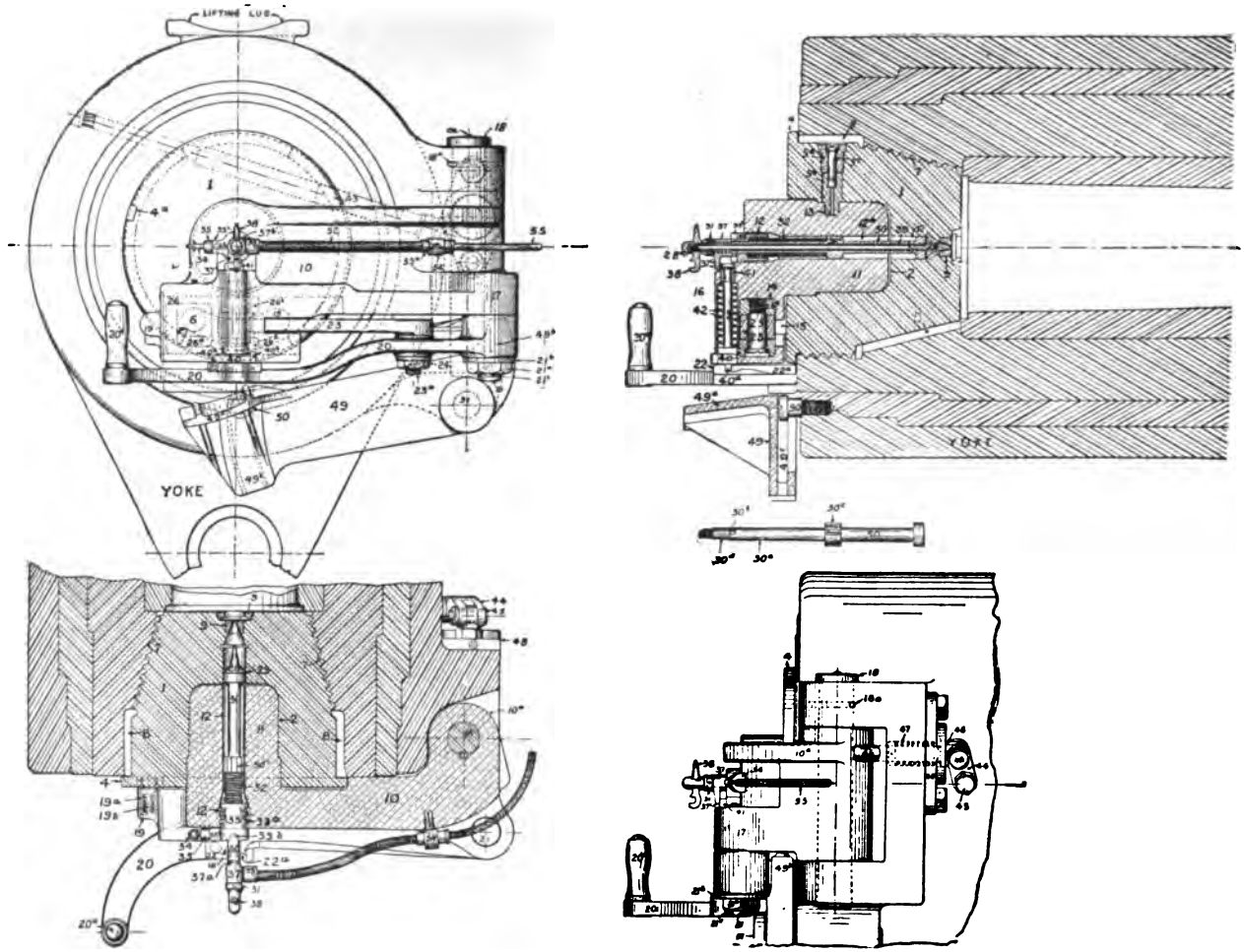
52. The English-built cruisers Albany and New Orleans are armed with Elswick 4.7-inch and 6-inch R. F. Guns. Their breech mechanisms are operated in a manner which to some extent resembles that of the 3-inch Mark II described above. The system is briefly described as follows (see Plate V): The conical breechblock is supported by and turns on a forward projecting circular boss of the carrier, the block being recessed for the purpose. The carrier is hinged to the right side of the gun. A guide-bolt stud passing through the block into a groove in the boss prevents the block from coming off and limits the rotation.

53. A horizontal hand-lever having a handle on the left end is hinged at the right end by a vertical pin to a lug on the carrier. In a transverse slot in the carrier beneath the boss slides a block, in which fits a rear projecting " rotating-pin " on the rear face of the block. The block is connected to the hand-lever by a short link, called the " rotating-link."

54. The breech being closed, by pulling the hand-lever to the rear, first, the rotating-link pulls the sliding-block to the right, and thus revolves the block on the carrier's boss to the unlocked position, the revolution being stopped by the block's guide-bolt; second, the center of movement is now transferred to the carrier's hinge-pin and the block and carrier then swing out clear of the screw-box on the hinge-pin as an axis. At the moment the carrier clears the breech-face of the gun, the plunger of a spring-catch, contained in a box on the left side of the carrier, is freed and enters a cut in the block's rim, preventing any revolution of the block in the carrier while out of the screw-box.

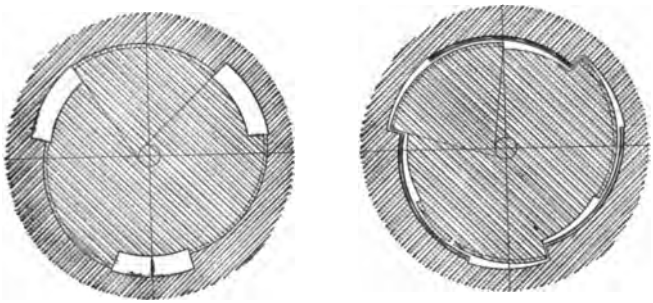
Bethlehem Breech Closure.

55. The cruiser Baltimore is armed principally with 6-inch R. F. guns constructed by the Bethlehem Steel Co. The breech



ELSWICK BREECH MECHANISM.

mechanism, called the Bethlehem Breech Closure, employed in these guns, is operated by a gear somewhat similar to that of the 3-inch Mark II mechanism. The breechblock, as in the Vickers' mechanism, has a holding surface comprising about two-thirds of the circumference, and it is slightly coned to facilitate swinging without translation. The blank portions of block and screw-box are cylindrical, but the threaded portions are involutes of circles which insures a firm and even contact. The threads are simply collars having no pitch, and hence give no motion of withdrawal to the block while rotating; this motion is obtained from the form of thread on the hub of the carrier by which the block is secured. This is possible only because the collars begin



BREECH CLOSED.
Collars on Block and Gun Engaged.

BREECH OPEN.
Block Free to Swing.

BETHLEHEM BREECH CLOSURE.

to disengage as soon as they start to revolve and may move to the rear slightly even when the unlocking is only begun; this feature should also eliminate much friction and make rotation easy.

CHAPTER X.

THE DRIGGS-SCHROEDER R. F. BREECH MECHANISM.

1. The Driggs-Schroeder mechanism belongs to the rotary-block system of breech closure in which the block rotates on a horizontal transverse axis, the upper part of the block falling to the rear; a slight vertical motion is required in locking and in unlocking, in which respect the system is the same as that of the sliding wedge.

2. The Driggs-Schroeder mechanism is used in the service in 1-pounder, 3-pounder, 6-pounder, and in two 4-inch R. F. guns, all of which use the service ammunition. As all secondary-battery guns to be built in the future will be of the semi-automatic or automatic type, no more D.-S. guns are being constructed. There are three marks; the first two differ considerably, while Mark III differs from Mark II only in the operating lever. All three are shown on Plate I.

3. The principal parts of the mechanism are: the *breechblock;* the *guide-bolts;* the *axial-bolt* and *main-cam;* the *operating lever* with its locking device; the *extractors;* and the *firing mechanism.*

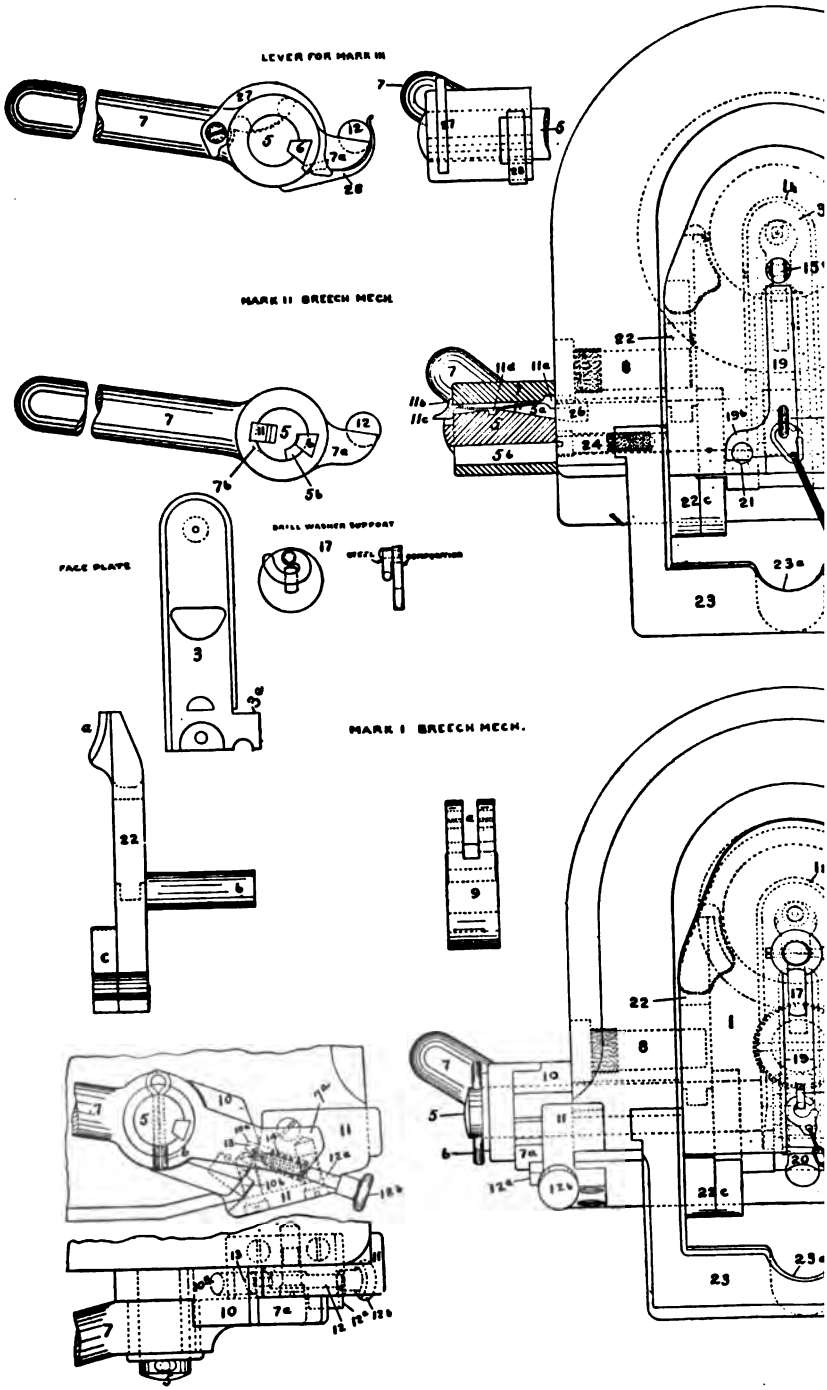
4. The breechblock (1), an irregularly shaped piece of steel, houses in the rear end of the gun's jacket, which is open at the rear and the under sides only; the sides of the housing, called the curtains, extend downward and terminate in the plug-rest (23). The locking is effected and the shock of discharge taken by the engagement of the bands (1 A) in corresponding grooves in the sides and top of the housing. The bands of the block and the grooves of the jacket are inclined about 2½° to the front so that as the block is pushed up into position in locking it is also pressed forward, forcing the cartridge case home: in unlocking it readily detaches itself from the case. The top of the innermost band is sloped away in order that the block may unlock and swing back-

ward with a minimum of downward motion. The firing-pin recess (1 D) is mortised out from the front and below, and, connecting with it by a narrow groove, a cavity is cut in which the main-cam (9) operates; the surfaces (1b) on which the cam bears, are essential to the operation of the block, as is the rounded portion (2); (1c) is a three-cornered piece of steel riveted in place and the cam bears on its upper surface during the first step in unlocking.

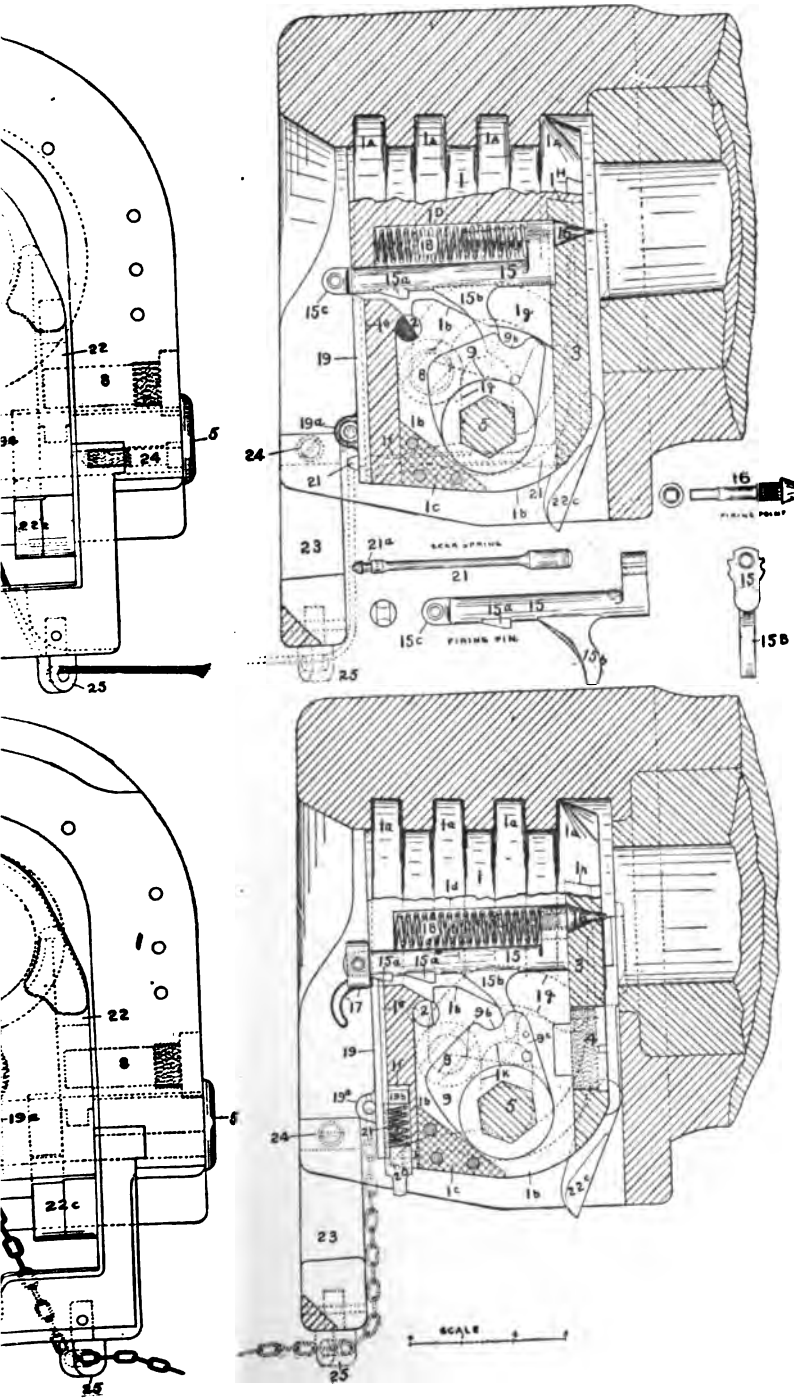
5. The front face of the block is closed by the dove-tailed face-plate (3); in the Mark I mechanism it is retained in place by the screwed plug (4); in subsequent marks the straight sear-spring (21), being inserted from the front through block and face-plate, serves as a face-plate keeper as well as a sear-spring. The sear (19) works in a vertical slot in the rear face of the block which in the Mark I mechanism also affords a recess for the *spiral* sear-spring (21). The *guide-bolts* (8) are screwed through the curtains of the breech and their ends take in the guide-bolt grooves (1g) of the block; these grooves are cammed surfaces so shaped that the guide-bolts give proper direction to the motion of the block induced by the main-cam; in most mechanisms the grooves are continued to the front of the block (as shown in Mark II), and in no case do the guide-bolts retain the block in place in the gun, that being a function of the axial-bolt; in the Mark II type and in many of the Mark I mechanisms the block may be dismounted without screwing out the bolts.

6. The axial-bolt (5) is cylindrical except for the hexagonal portion that engages the main-cam—the right end of the bolt is of greater diameter than the left end. The bolt passes through both curtains of the breech and through the block; the hole in the latter is lengthened in a nearly vertical direction to permit the block to descend for unlocking. The main-cam (9), an irregularly shaped piece of metal, rotates with the axial-bolt; its working surfaces are on its rear and upper sides and the notch (9b) catches the rounded portion (2). The top is slotted out to form a cammed groove which presses the firing-pin rearward by acting on its projecting portion (15b).

7. The operating lever (7), on the left of the breech, differs in the three Marks, in its locking device; in Marks I and II, it has



DRIGGS-SCHROEDER



REECH MECHANISM.

from the closed position a slight free motion before the axial-bolt starts to revolve.

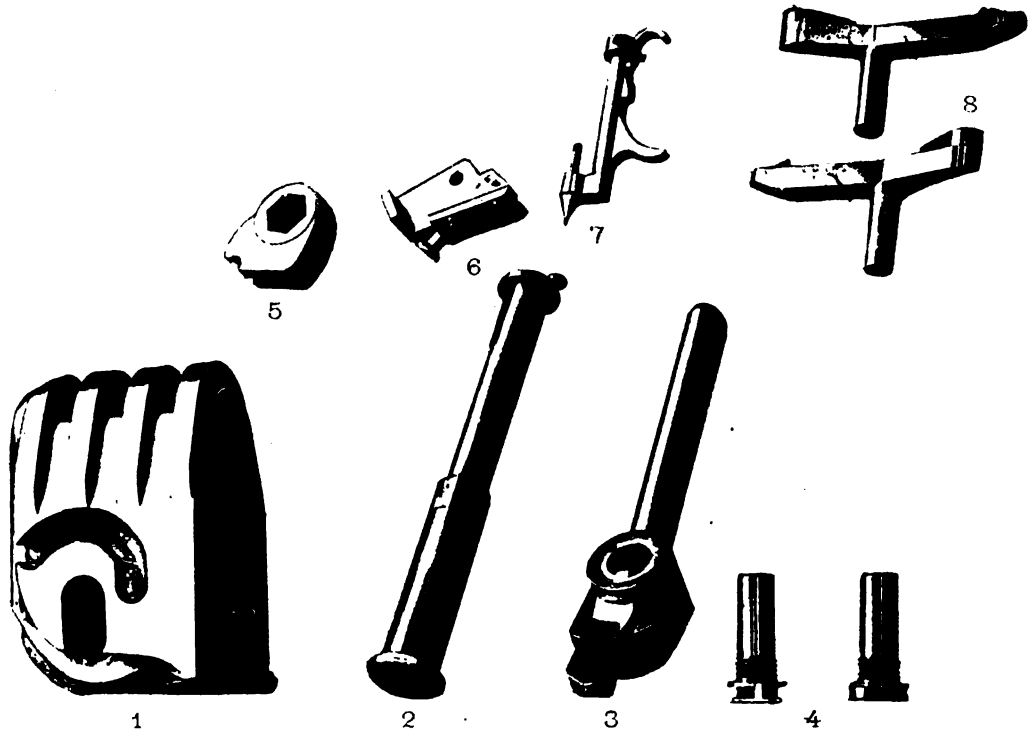
8. In the Mark I device, the lever-locking piece (11) is secured to the left curtain of the gun; it contains the locking-pin (12), with its head (12b) and lug (12a), all pressed inward by a spiral spring. The operating lever, with (10), is secured to the axial-bolt by a split-pin (6); the lever has a little lost motion in (10) but the latter is however held rigidly to the axial-bolt by a feather. When the breech is closed, the end of the locking-pin rests in a recess in (10) and the bolt cannot be rotated except by its lever, the tail (7a) of which must first disengage the locking-pin by pressing outward on (12a). In closing, the pin is snapped into place in a similar manner and the lever is brought up by its stop (10b); the weight of the lever in all Marks aids in retaining the breech closed.

9. No locking device is employed on the Mark II operating lever which, in place of a split-pin, is secured by a spring-catch (11) lying in a recess in the axial-bolt; as far as (11) is concerned, the lever turns freely on the bolt, but the feather (6), working in a slot wider than itself, limits the scope of this free motion. The lever is brought up when the breech is closed by the stop (12) which is screwed into the curtain.

10. The lever of the Mark III mechanism is keyed to the axial-bolt without lost motion and is secured by the lock (27) which snaps over the hub of the lever and enters a slot in the end of the axial-bolt. The locking device consists simply of a spring (28) secured to the hub which slips over the stop (12).

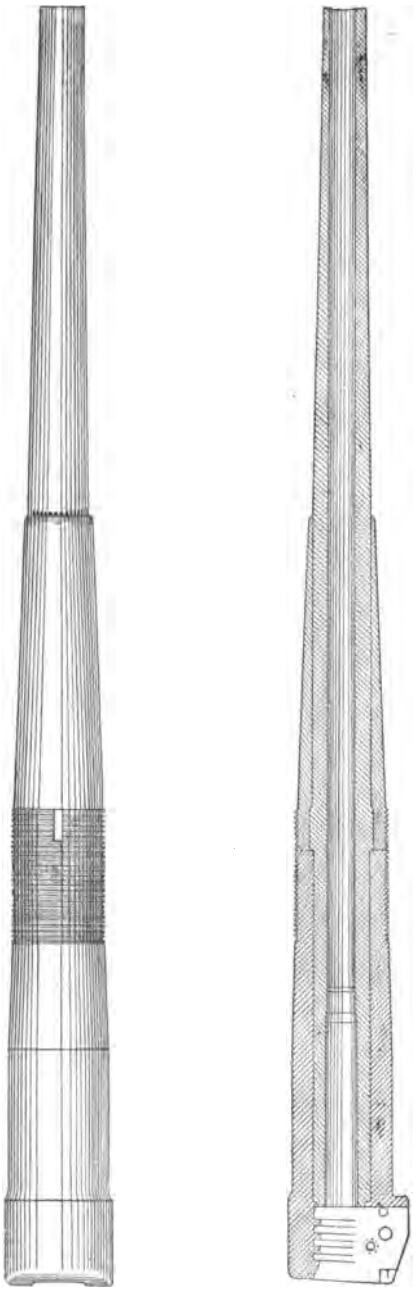
11. The extractors (22), pivoted from the inside to the curtains of the breech, rest, when the breech is closed, with their upper ends grasping the rim of the cartridge case; their lower ends (22c) are so formed that, as the breech is opened, the lower side of the block will cause them to move forward at first slowly then abruptly, whereupon their upper ends will forcibly eject the case from the gun. One extractor will as a rule eject satisfactorily in case the other is broken.

12. The operation of the mechanism, not considering the firing mechanism, is as follows: (The description is given for



MARK I DRIGGS-SCHROEDER MECHANISM DISMOUNTED (MOVING PARTS).

1. Breechblock. 2. Axial-Bolt. 3. Operating-Lever. 4. Guide-Bolts. 5. Main-Cam.
6. Lever Locking-Piece. 7. Firing-Pin. 8. Extractors.



DRIGGS-SCHROEDER 6-POUNDER, MARK II, AND DRILL CARTRIDGE.

the Mark I mechanism from which the later Marks may be readily understood.)

13. *Opening,* in which the weight of the block materially assists: The operating lever having free motion, its first movement unlocks the axial-bolt and main-cam which it then rotates. As the main-cam moves rearward, its upper corner leaves the surface (1b) by which it had held the block upward; then the cam's rear surface presses downward on (1c) and the block drops downward, freeing the bands. This vertical motion is stopped by the axial-bolt, the guide-bolts change it to a rotary one and the cam engages (2) and presses it rearward until the block lands in a horizontal position on its rest (23). The lower side of the block is slightly eccentric with the bolt and during the latter part of opening it cams the tails of the extractors forward at first slowly and with great leverage, starting the case from its seat; then more quickly, causing complete ejection.

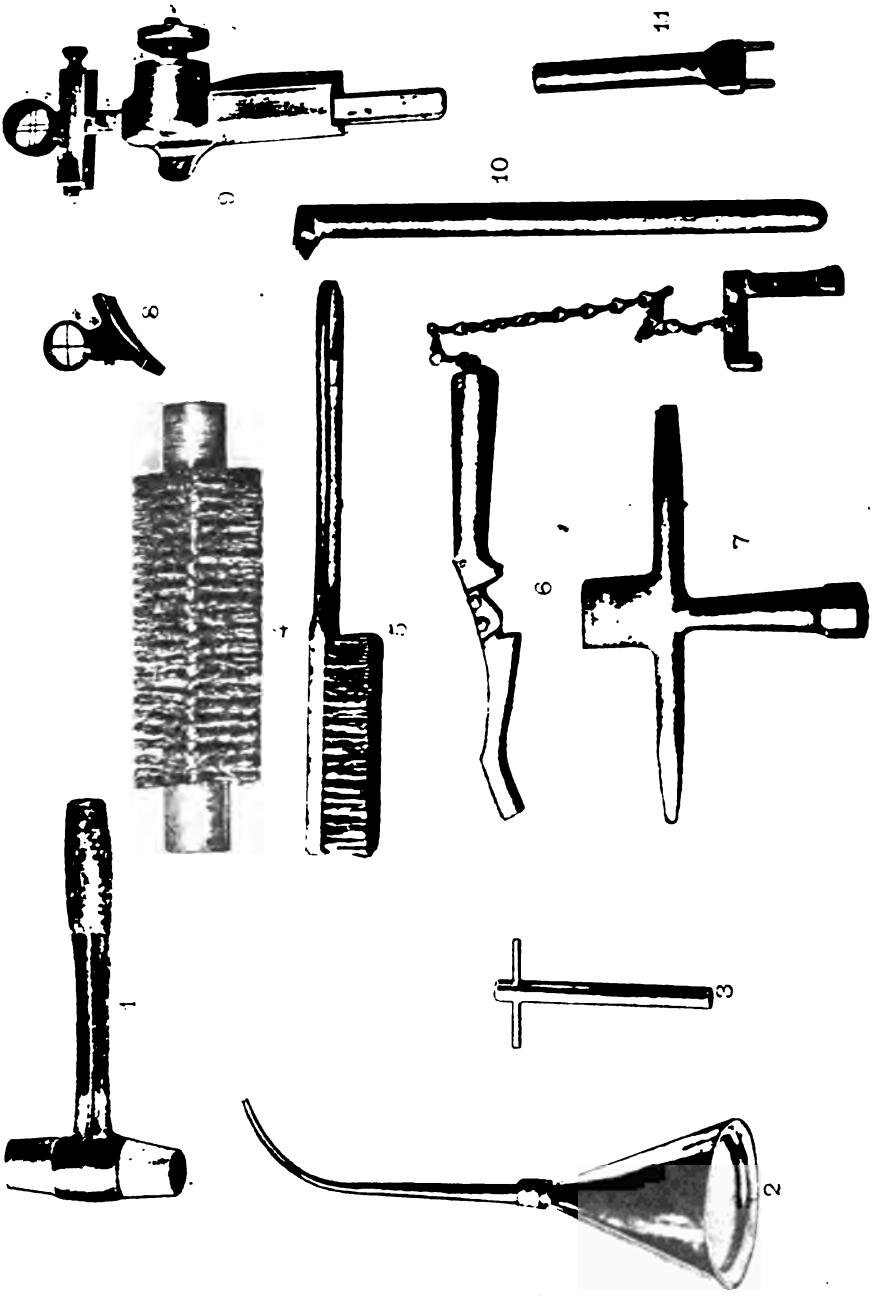
14. *Closing,* in which the weight of the block is raised: The cam being still engaged with (2) and the rear part of the surface (1b), which has followed it down, as the lever is thrown forward, the block is rotated until it strikes the cartridge case and forces it, with the extractors, nearly to its seat; at this moment the guide-bolts reach a (nearly) vertical portion of their grooves and the rotary motion is changed to a vertical one. The cam now leaves (2) and its upper corner follows along the surface (1b) and presses the block upward until locking is effected. During the last part of the cam's rotation its upper corner moves along a part of (1b) which is concentric with (5); no motion of the block results from this but the upper corner of the cam is brought forward of the center of rotation and the weight of the block then tends to force it still farther in the same direction. This provision, added to the weight of the operating lever, its inertia in recoil and its locking device, if used, effectually prevents the breech from being opened by other means than the operating lever.

15. The firing mechanism consists of: the firing-pin with firing-point and support; the firing-spring; the sear and firing-lanyard; and the sear-spring. The firing-pin (15) is inserted from the face of the block into a recess in which it operates; it

projects through the rear of the block. The firing-point (16) is screwed to a lug on the end of the firing-pin and the firing-spring lies in a recess directly in rear of it. The cocking-notch (15a) (there is a half-cock notch in the Mark I mechanism), is on the under side of the pin and the tail (15b), by which the mechanism is cocked, projects downward and bears on the main-cam. A thick rubber "drill-washer," designed to receive the blow of the firing-pin in exercise, is secured to the firing-pin by the drill-washer support (17). In the Mark I mechanism, the support is left on in firing and a finger-catch is added for convenience in easing down the firing-pin and recocking. In later Marks the support is removed before firing and a hook from the accessory box must be used if the firing-pin is to be handled while the breech is closed. The sear (19) is a thin bar working in a dove-tailed groove in the rear face of the block. The firing-lanyard hooks to an eye (19a) on its surface, thence passes through the leader (25) to the trigger on the shoulder-stock. The sear-spring of the Mark I mechanism is spiral and is compressed between a plug (20), closing its recess, and the lug (19b) of the sear. The sear-spring of the later marks, serving also as a face-plate keeper, is a slender rod inserted from the face of the block and bearing on an extension (19b) of the sear.

16. *The cocking of the mechanism* is accomplished while the block is being unlocked; the main-cam, by a cammed groove cut in its upper end, presses the firing-pin to the rear by the projection (15b) until the sear snaps over the notch (15a). The firing-point is drawn inside the face-plate and the cocking is nearly completed before the block starts downward.

17. Safety.—Although the firing-pin is cocked and the firing-spring compressed before the breech is closed, a premature discharge with D.-S. mechanism is impossible because: (1) The main-cam is in a position to arrest the blow of the firing-pin, until the locking is completed. (2) Even if the firing-pin be sprung forward or projects through the face-plate during closing, because of an injury, or other reason, it is impossible for it to strike the primer, as its point is not in line with it until the block is very nearly locked. However, it is possible to swing the block upward forcibly enough to give the base of the cartridge a severe blow that might explode the primer by concussion.



SIGHTS AND ACCESSORIES FOR MARK I DRIGGS-SCHROEDER GUN.

1. Babbitt Mallet. 2. Oil-Can. 3. Firing-Pin Wrench. 4. Sponge-Brush. 5. Cleaning-Brush. 6. Block-Support. 7. Combination Screw-Driver. 8. Front Sight. 9. Rear Sight. 10. Hand-Extractor. 11. Face-Plate Drift.

18. The following advantages are claimed for the D.-S. mechanism over other R. F. breech mechanisms.

(1) The lightness of the mechanism and the rotary system of operation conduce to a greater rapidity of fire; it also permits a greater length of bore for the same weight which results in greater muzzle velocity.

(2) One man is able to load and at the same time operate the block; for this purpose the lever is placed on the left side and the loading operation does not obscure the gun-pointer's view of the sights.

(3) There is no opening in the top of the breech through which rain and dirt may enter the mechanism.

(4) With the breech open as well as with it closed, the block and entire mechanism, save the lever, remain within the curtain and are entirely protected.

19. Plate II shows the Mark I mechanism disassembled. Plate III shows the construction of a D.-S. gun and its drill cartridge.

(1) An *accessory* box is furnished with every pair of guns and contains the following:

(2) *Accessories.*—Hand-extractor, combination screw-driver and wrench, babbitt-metal mallet, face-plate drift, oil-can, firing-pin wrench, cleaning-brush, bristle-bore brush, block-support, drill-washers, and, for Marks II and III guns, a hook for handling the firing-pin.

(3) *Spare parts.*—Firing-pin, firing-springs, right and left extractors, sear, sear-springs, and a set of gun-screws. (Plate IV shows the sights and accessories for a Mark I gun.)

CHAPTER XI.

HOTCHKISS BREECH MECHANISM.

1. The Hotchkiss breech mechanism for rapid-firing guns belongs to the sliding-wedge system of fermeture—the block or wedge is lowered to open the breech. This mechanism is very generally used for United States naval guns, being employed in the 1-pounder, 3-pounder, 6-pounder, 9-pounder, and 14-pounder calibers. The mechanisms of these various sizes differ in the details—the two 9-pounders, the three 14-pounders, and many guns of the other calibers having been purchased from French and British firms. However, there are but two standard navy types—Marks I and II; the latter, which has spiral instead of flat springs, is often called "the 1893 model." The mechanisms for 3-pounder and 6-pounder guns are in all respects similar in their working parts except as regards size; that for 1-pounders has minor differences which will be described. Since secondary-battery guns to be built in the future will be semi-automatic, the construction of Hotchkiss mechanisms of the ordinary R. F. type is discontinued, but the system is readily adapted to work semi-automatically as will be described in chapter XXII.

2. The principal parts of the mechanism are: the *block;* the *crank* with crank-stud and operating handles; the *stop-bolt;* the *extractor;* and the *firing mechanism,* consisting of *hammer, rock-shaft, firing-point, firing-spring, sear,* and *sear-spring.*

3. The Hotchkiss mechanism for 6-pounder R. F. guns, Mark I (Plate 1).—**The Block** (1) is a rectangular wedge-shaped piece with rounded corners, hollowed out to contain the firing mechanism, that moves vertically in the breech-mortise of the gun, being guided by a groove (4) on each outer side working on ribs in the sides of the mortise. These ribs are slightly inclined upward and to the front. The front face of the block is perpendicular to the axis of the gun, while the rear face is in-

clined downward and to the rear, so that in opening, the block has a slight movement to the rear, and, in closing, to the front, thus giving great power in the first part of extracting or last part of loading. The upper side is hollowed out to uncover the bore in opening, and to form a loading trough; and the front upper edge is beveled to facilitate pushing the cartridge into the chamber. On the right side, in a nearly fore-and-aft direction, is cut the "crank-slot" (2), a groove running out to the front face of the block; the front part is concentric with the crank-stem, while the remainder is cammed. On the left side is the (nearly) vertical "stop-bolt groove" (5), in which the end of the stop-bolt engages, to guide the block and prevent its dropping out of the gun in opening, and the "extractor-groove" (3), the lower part being slightly inclined upward and to the rear, while the upper part makes a sudden turn to the rear. On the front face is a dovetail groove, for the "face-plate" (6). When the block is closed, its rear face fits tightly against the rear face of the breech-mortise, removing all strain from the guide-ribs on firing. The *recoil or face-plate* (6) is a hardened steel plate, dovetailed from the bottom into the front face of the block and held by two screws (7). It covers the bore of the gun when the block is held up, and takes the direct recoil of the cartridge. It is pierced with a hole for the firing-pin's point that is in the axis of the gun when the breech is closed.

4. The stop-bolt (31) is a threaded bolt which screws through the left curtain of the gun. Its inner end works in the vertical groove (5) on the left face of the block, and prevents the latter from dropping out of the mortise. The outer end is shaped into a rectangular head, which bears against the gun when screwed in. A hole through the head is used for the dismounting-pin. This bolt was made of sufficient length to pass through the shoulder-stock on the non-recoil-mounted guns.

5. The crank (8) is in one with the crank-stud (9) and stem (10). It is worked by the crank-handles and is journaled in the right curtain of the gun. The arm lies within the mortise and a stud in its end works in the crank-slot of the block and gives to the latter the vertical drop (or lift) movement. The stud is flat

on top to prevent undue wear, and, when the breech is fully closed, lies past the center of movement and supports the block.

6. The crank-handles (11), or *operating levers* (two in number in one with a boss) and a toe are carried on and keyed to the crank-stem outside the gun and are secured to it by the lock (13) which is pivoted to the boss at one end and snaps down over it, engaging a recess in the crank-stem. A split-pin lock is employed in some of the earlier guns. The toe (12), known as the "cocking-cam," projects downward and to the rear, and bears on the rocking-shaft or "cock-toe," when the hammer is not cocked. Thus the movement of the handles to the rear will in the first place result in cocking the hammer, while the continued motion lowers the block. A flat spring with a rib on the inner side, called the "crankhandle-catch" (14), is held by a screw in a groove on the inner side of the cocking-cam. When the breech is closed, this spring-latch seats itself in a small hollow in the curtain of the gun and holds the handle in the locked position. It requires a deliberate movement of the handle to the rear to unseat the catch.

7. The extractor (28) is a straight flat bar, shaped on its upper and lower edges to slide in a longitudinal T-shaped groove in the left cheek of the gun's mortise. The forward end is bent inward to form a claw or "nib" (29) to take under the lip of the cartridge case. On the inner side is a beveled stud (30) that travels in the extractor-groove (13) of the block, by which a fore-and-aft movement is given to the extractor, when the block is moved up or down. The stud keeps the extractor in the gun.

8. The firing mechanism.—The *hammer* (15), of the old gun-hammer style, is in one with a hollow shaft (16) or axis. It is mounted in the middle line of the block's cavity on the "rock-shaft" (21), and is actuated by the latter, working freely in the block's cavity. The firing-point is made detachable, but was formerly in one piece with the hammer. A cock-notch is provided on the axis for the "sear."

9. The stirrup (19) is hinged to the hammer-axis, front side, in the center line, and is provided with an arm on each side to form a rest for the end of the lower branch of the mainspring,

which is split. Part of the stirrup, of segment shape, normally projects through a slit into the hollow of the hammer-axis, fitting in a slot (23) on the rock-shaft to lock the hammer and shaft together and prevent the latter from coming out. This locking is in effect as long as the mainspring is in place holding the stirrup in the proper position.

10. The firing-pin (20c) is a conical point with a split shank (a) forming ears (b) which fit over a groove in the front end of the hammer, and is held in place by the spring action of the ears. Thus a new firing-point can readily be put in place in case of breakage.

11. The rock-shaft (21), a transverse horizontal shaft, carrying on its right end the "cocking-toe" (22), journals in the lower forward part of the block, and, where passing through the hammer-axis, is made hexagonal. The toe, being pushed downward by the cocking-cam (12) on the operating handle, turns the shaft to the rear about its axis and hence moves the hammer to the rear (cocking it over the sear), and compresses the mainspring.

12. The mainspring (24) is a double-branched flat spring, more or less V-shaped, the bend seating in a rest in the middle of the block, the open end forward. The end of the upper branch is shaped into a roll seating in the after side of the hammer-axis in a jog (18) while the lower branch's end is split and rounded out to pass over the arms of the stirrup forward of the hammer-axis. When so placed, with the hammer forward, the spring is in slight tension, which keeps it in place. On moving the hammer to the rear, the two branches of the spring are brought together, which gives the force or tension to throw the hammer forward about its axis when released.

13. The sear (25) is a small thin bar of steel pivoted on a stud (26) in the right forward corner of the block's cavity, and has a rib or claw which engages the cock-notch on the hammer-axis when the hammer is drawn fully to the rear. The after end of the sear projects slightly to the rear of the block, where it is engaged by the trigger-arm. A small groove on the lower face forms a seat for the front end of the sear-spring.

14. The sear-spring (27) is a thin bar seating in a dovetail in the lower face of the block. The forward end is thinned and bears on the sear to keep it in position to hold the hammer cocked.

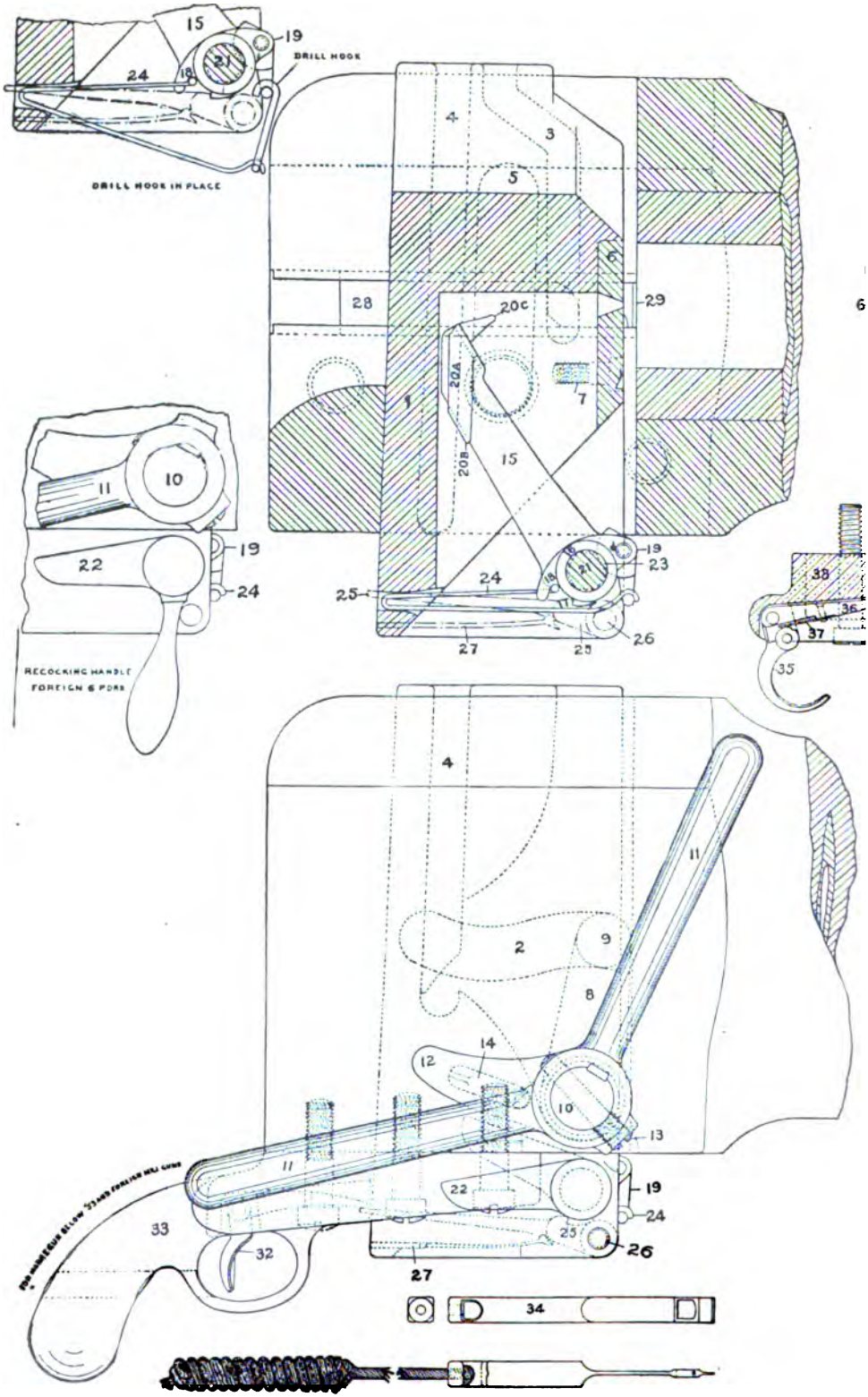
15. The trigger (32).—A bronze "pistol-grip" (33), secured to the rear of the gun on the right side, carries a loose trigger (32) (*i. e.*, one without a spring), which is a bell-crank pivoted at the bend. The front end is in contact with the sear when the block is closed, while the rear end projects downward to form a finger-grasp, which, if pulled to the rear, results in forcing down the sear to release the hammer, and thus fires the gun. On guns beyond No. 53, the pistol-grip with loose trigger is replaced by a "trigger-box" (38), screwed to the gun, which contains a trigger-pull (35) actuating a trigger-lever (36) which bears on the sear. The lever has a flat spring (37), the rear end of which bears on the hub of the trigger, with a little boss that takes in a cut in the trigger when it is desired to turn up the latter for safety.

16. On recoil-mounted guns a lanyard is attached to the trigger, going through a hole in handle of pistol-grip, if provided.

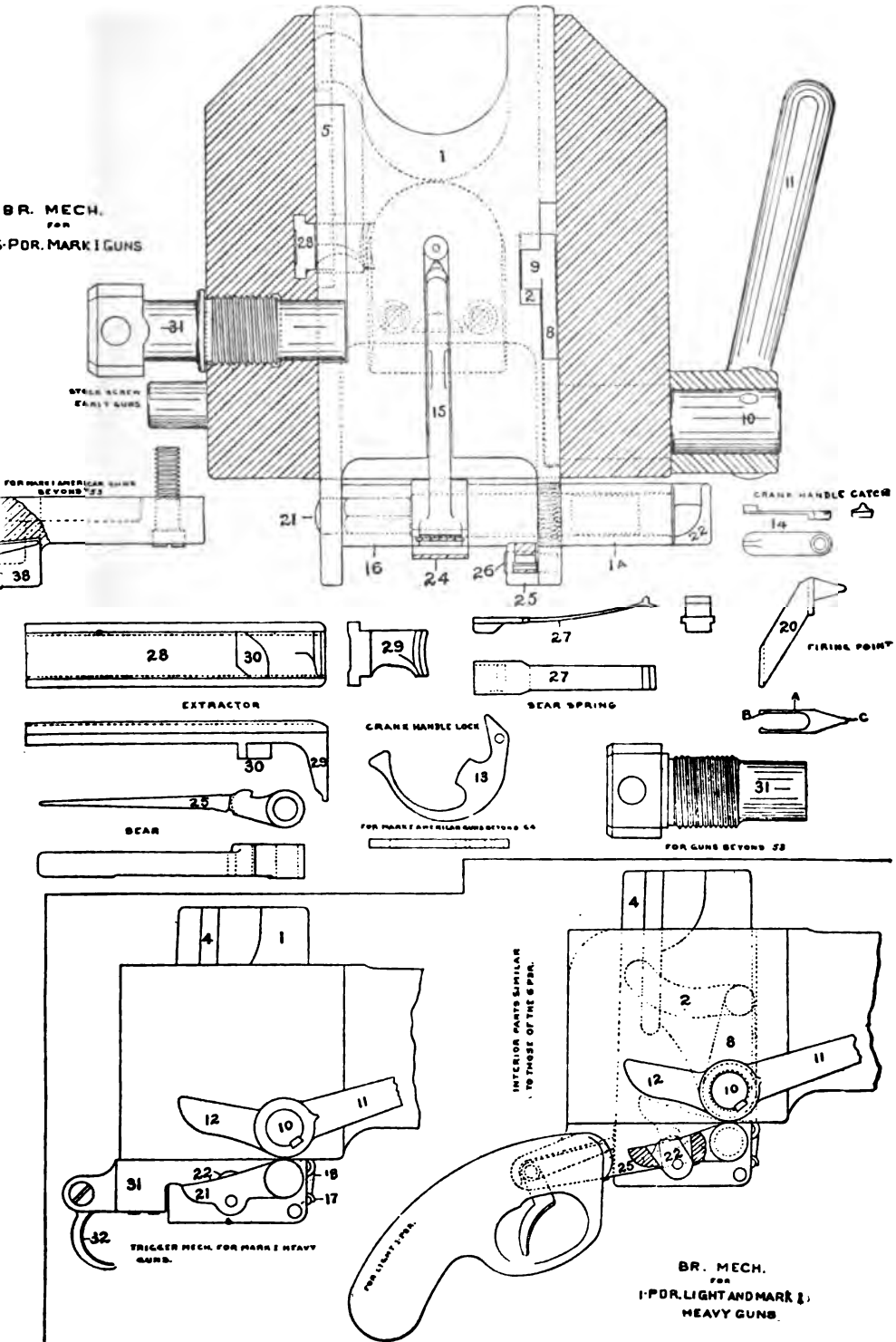
17. The drill-hook for the Mark I 6-pounder and 3-pounder Hotchkiss breech mechanism is made of round wire, open at the top, the arms being bent to form hooks. It is designed to relieve the mechanism from strain when snapping the gun on drill; to protect the point from being injured by its shoulder striking heavily on the face-plate, which tends to crystallize the metal; and to relieve the mainspring from strain on ordinary occasions. It hooks to the stirrup and the lower branch of the mainspring, which is unshipped from the stirrup. On "casting loose" for actual firing, the drill-hook is removed and mainspring hooked to stirrup. For subcaliber practice, however, the hook is left on, as the blow of the firing-pin will be sufficiently strong.

18. The action of the Mark I breech mechanism is as follows (suppose the gun fired and an empty case in the chamber):

(1) *Opening.*—The breech is opened by pulling the crank-handles to the rear. The crank-stud moves to the rear in the groove, the block descends by the cam action of the inclined part of the groove and by its own weight, until arrested by the stop-bolt, when the bore of the gun is completely unmasked.



1-PDR. AND 6-PDR. HOTCHKISS



BREECH MECHANISM, MARK I.

(2) *Cocking.*—As the crank begins to move to the rear, its stud first passes over that part of the groove which is concentric with the crank-stem; hence no motion results to the block. But during that period the cocking-cam bears down the cocking-toe, turns the rock-shaft to the rear about its axis, and cocks the hammer, which is held cocked by the cock-notch being engaged in the sear. The mainspring is also compressed at the same time.

(3) *Extraction.*—As soon as the block begins to descend it moves slightly to the rear, due to the inclination of the guide-ribs; hence the extractor moves slowly to the rear with great leverage and the case is started from its seat. When the block has descended sufficiently to unmask the bore, the abrupt change of the extractor-groove to the rear gives a violent motion to the extractor which ejects the cartridge case.

(4) *Loading.*—The cartridge is entered in the chamber until the rim of the case strikes the extractors' nib. On closing or raising the block, the beveled upper corner shoves home the cartridge and the extractor moves to the front.

(5) *Closing.*—The breech is closed by moving the crank-handles forward. When closed, the crank bears against the face of the gun-tube, beyond the center of motion, and its stud supports the weight of the block. The face of the block now bears closely against the head of the cartridge.

(6) *Firing.*—The breech being closed, the cocking-cam and cocking-toe are separated. By pulling the trigger (or lanyard attached to it), the trigger-arm bears down on the rear projecting end of the sear and releases it from engagement with the hammer, which now flies forward under the action of the compressed mainspring; the firing-point, passing through the hole in the face-plate, strikes the primer-cap, which explodes and thus fires the gun.

19. The Hotchkiss Mark I mechanism for 1-pounders (Plate I) is in its interior parts the same as for the heavier guns except that there is no drill-hook. There is but one crank-handle instead of two; in the rock-shaft cocking-toe is set a "fly" (2) on which the cocking-cam bears. The fly is used to prevent too great friction, since the sweep of the lever in cocking is very great. The trigger is held in a pistol-grip, for the light 1-pounder or non-

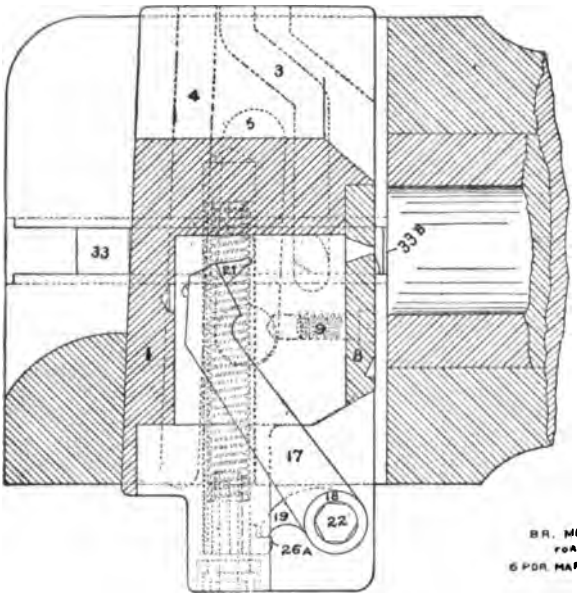
recoil mounts. For heavy 1-pounders, the trigger and trigger-box are like that for the 6-pounder guns beyond No. 53.

The Hotchkiss Mark II 6-pounder Breech Mechanism.

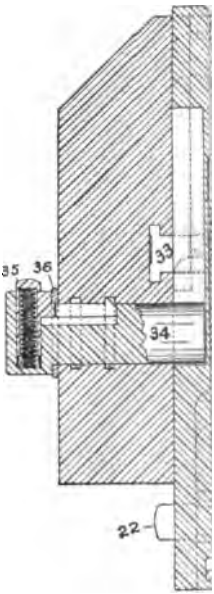
20. The block (1) (Plate II), with all its moving parts *as a whole,* is interchangeable in the breech-mortise of the Mark I gun. It is of the same general shape as the Mark I, but differs as follows: There is a vertical circular hole (6) open at the bottom, forming a pocket for the spiral mainspring (25), on the left side, and a similar but smaller pocket (7), on the right side, for the sear-spring (32), both opening into the lower face of the block. Near the bottom of the former is an annular groove for lip of the mainspring lock (27). To the left of the block's central cavity a groove is cut into the mainspring pocket to permit the engagement of the mainspring sleeve on the hammer-shaft. On the right side of the block's central cavity, a sear stop-plug (16) guides the movement of the sear and is screwed into the block, remaining as a permanent fixture. It also prevents the sear from coming off its pin, in the usual position. "The crank-slot" (2) has an indentation on the upper forward end (in some of the blocks) in which the stud (11) of the crank rests when the breech is closed.

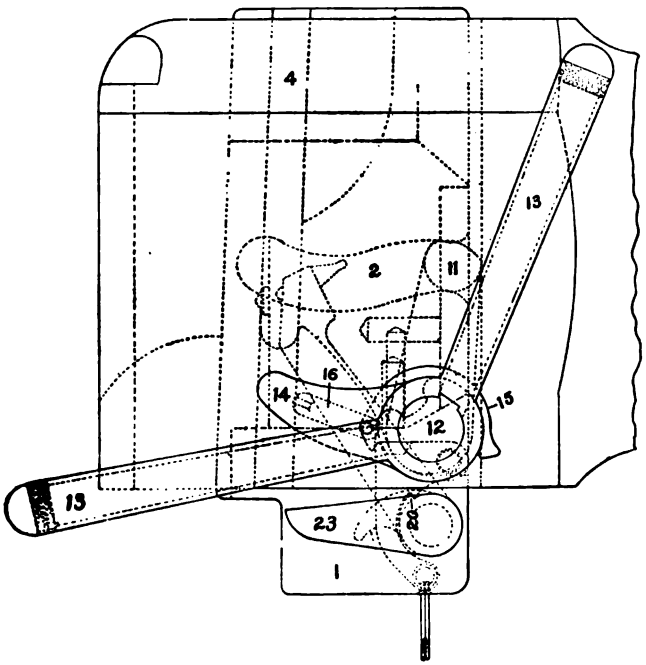
21 The stop-bolt (34) is not threaded, but is provided with a milled head on the outer end and a "spring lock" (35). This lock consists of a hollow sleeve, within which is a spiral spring, seating in a vertical hole in the head of the stop-bolt, and an arm, in one with the sleeve, which lies in a longitudinal cut in the bolt. The inner end of the arm has a toe which engages in one of two annular grooves cut in the stop-bolt hole. The lock is retained on the bolt by a ring or washer (36). To operate the lock, it is only necessary to press down on the sleeve, which moves the lock and will disengage the toe from the one of the grooves in the stop-bolt holes. These grooves are so arranged that when the toe is in the outer one the stop-bolt is just clear of the block, while if engaged in the inner one the bolt enters the groove in the block. This facilitates mounting or dismounting the block.

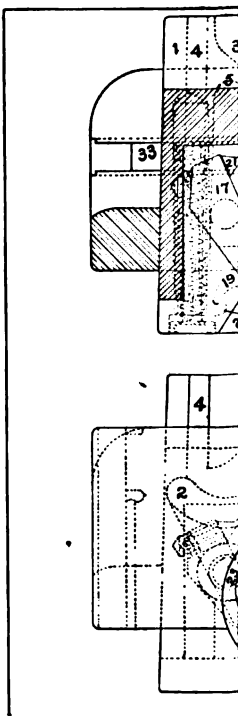
22. The crank-handles (13) are held on the stem of the crank



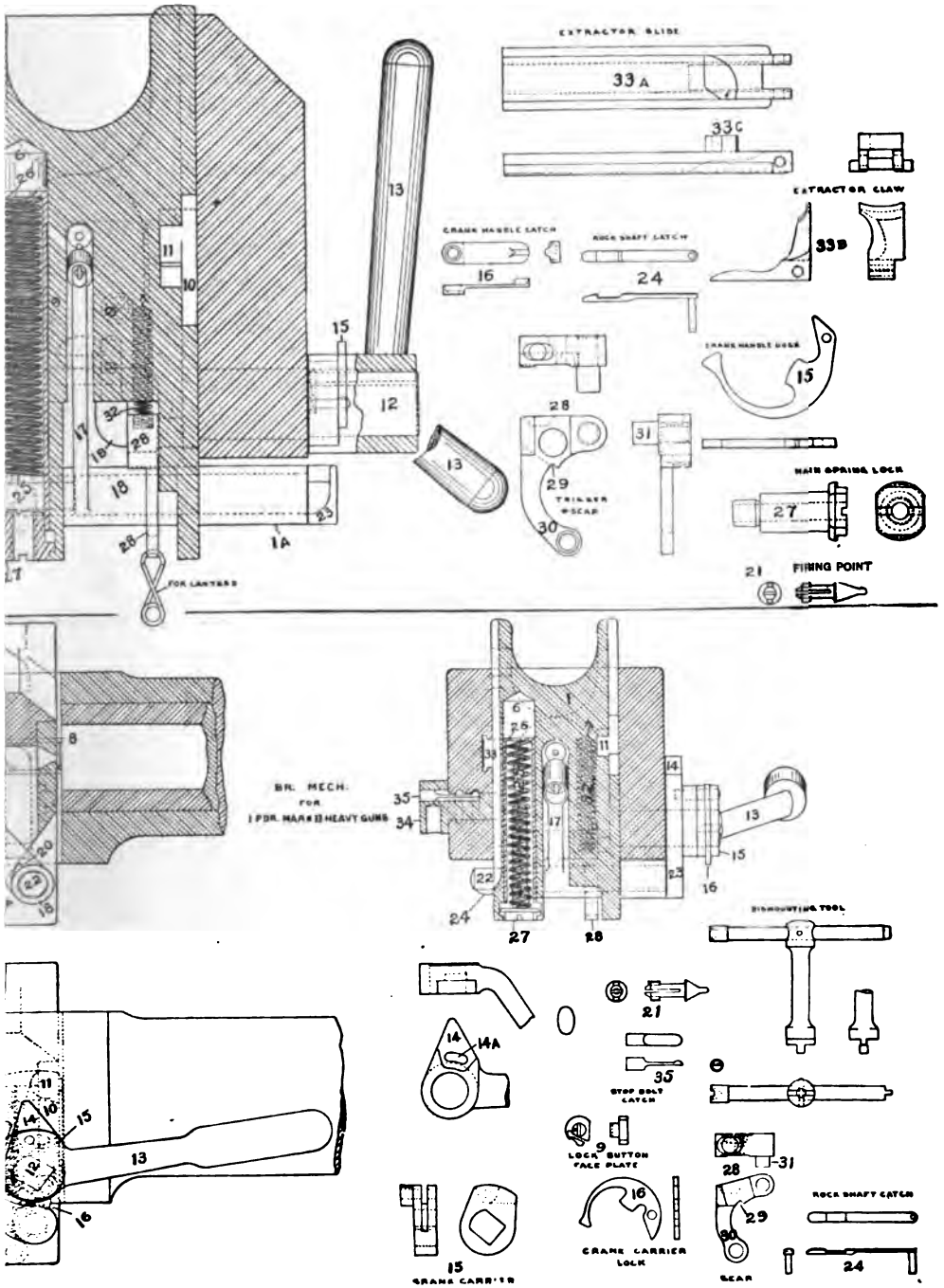
BR. MECH.
FOR
6 PDR. MARK II GUNS.







HOTCHKISS BREECH



MECHANISM, MARK II.

by means of a feather and "crank-handle lock" (15), as described in the Mark I mechanism.

23. The extractor is also the same as previously described except that the claw is detachable and made of tempered steel, to make it more elastic.

24. The hammer (17) has a rearward projecting lug (19) on its axis on the left side, which bears on the toe of the mainspring sleeve; this lug receives the push of the mainspring to rotate the hammer about its axis for firing. The cock-notch (20) is on the right side.

25 The firing-point differs from the Mark I in being a conical point with a split shank having two lugs. In entering, these lugs are placed opposite grooves in the hole in end of hammer, when by pushing it in, and then giving a partial turn with the dismounting-tool, the lugs will engage behind the hammer-head, being sprung apart by the spring of their arms.

26. The rock-shaft (22) projects through the block on the left side and is provided with a spring catch (24) to hold it on (necessary because there is no stirrup to hold the shaft in place as in Mark I). This catch is a flat spring lying in a longitudinal slot on left end of the shaft; it has, on the outer end, a lug that slips over the edge of the hole in the block when the shaft is in place, preventing movement to the right.

27. The mainspring (25) is a strong spiral spring which seats in its sleeve and is retained in the block by the "mainspring lock" (27) at the bottom.

28. The mainspring sleeve (26) is a hollow steel cylinder, partially closed at its upper end, provided with a toe on the lower end which projects forward to engage the lug on the hammer-axis. Holding the mainspring, it slips in a vertical pocket (6) in the block, and is kept in place by the "spring-lock."

29. The mainspring lock (27) is a bolt with head cut away on opposite sides to form lips, and a slot cut in its top for the dismounting tool. It is put in place by passing the shank of the bolt up inside the mainspring and, with the dismounting tool engaged in the slot, pushing downward to compress the spring, and then turning to the right or left a quarter turn so that the lips enter the annular groove in the block. The pocket is slotted

on opposite sides to form the annular groove which permits the lips of the lock to be entered or withdrawn, and thus a bayonet-joint is formed.

30. The sear (28), of peculiar shape, is pivoted by a pin (31) on the side of the block as in Mark I. There are two arms, one thick and heavy and provided with a shoulder to engage the cock-notch on the hammer-axis; the other, or firing-arm (30), has in its extremity an eye for attaching the firing-lanyard, and thus acts also as a trigger.

31. The sear-spring (32) is spiral and seats in its socket (7) in the block, pushing down directly on the upper arm of the sear to keep the latter engaged in the cock-notch of the hammer when retracted.

32. DIFFERENCES BETWEEN MARKS I AND II 6-POUNDER HOTCHKISS BREECH MECHANISMS.

Part.	Mark I.	Mark II.
Block.....	As described.	Has two vertical holes in after part for main and sear-springs.
Crank-handle.	Attached to crank-stem by a feather and keep-screw, taper-pin or spring-catch.	Attached to crank-stem by a feather and spring-catch.
Hammer.....	Has a stirrup and sear for a flat mainspring.	Has a cocking-lug which bears on toe of mainspring sleeve.
Firing-point..	Has rear projecting spring ears clasping end of hammer.	Has spring split-shank resting in rear of hammer.
Rock-shaft...	Held to hammer-shaft by a projector lip on the stirrup.	Held in block by a spring-catch on the left end.
Mainspring..	Double-branched flat spring, ends held on opposite side of hammer-shaft.	Spiral spring which acts on lug of hammer through toe on sleeve.
Sear-spring..	Flat, free arm bearing on the sear.	Spiral, bears on arm of sear when in place.
Extractor....	In some, nib and body in single piece; others like Mark II.	Nib separate from body to assist in extraction by spring temper and for strength.
Stop-bolt....	Screws into seat.	Held in seat, and also when partly out, by a spring-catch working in annular groove in stop-bolt hole.
Trigger.....	Ordinary bent lever held in pistol-grip, one arm resting on free end of sear.	No trigger. Firing-lanyard hooks in arm of sear.

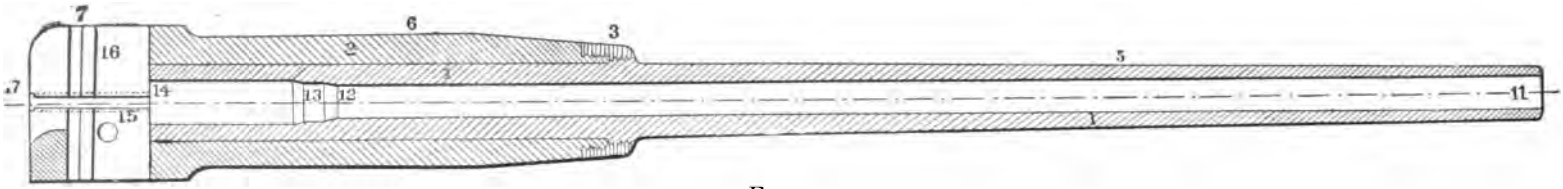


FIG. 1.

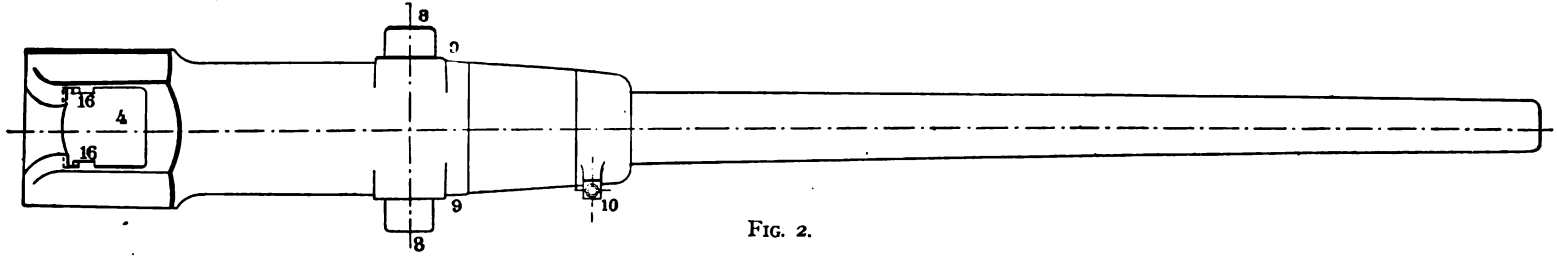


FIG. 2.

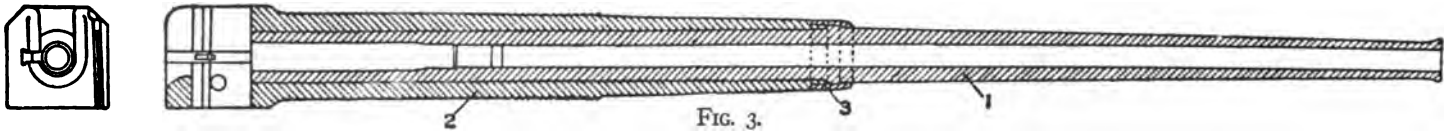


FIG. 3.

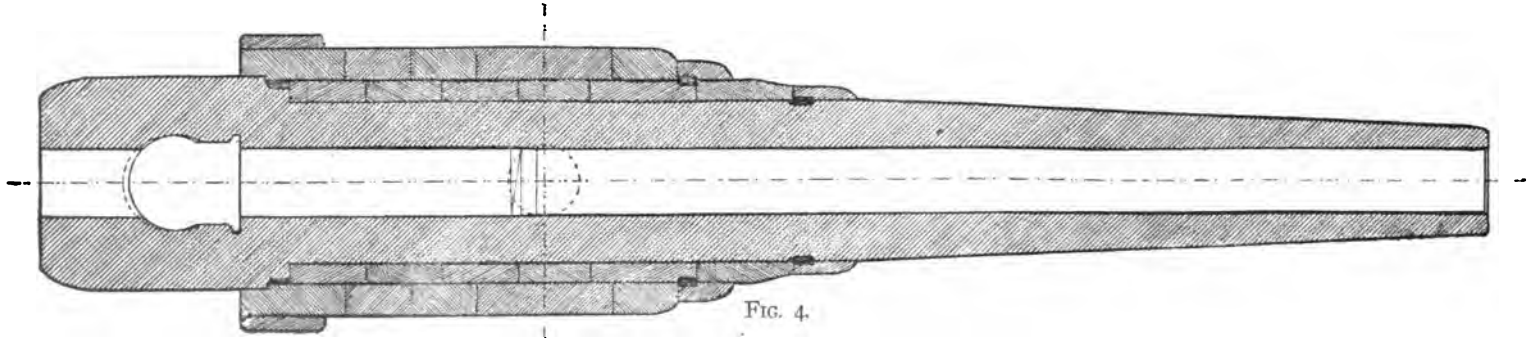


FIG. 4.

33. The Hotchkiss Mark II mechanism for 1-pounders (Plate II) employs a block similar to that for the 6-pounder gun except that the face-plate is secured by a " lock-button " instead of screws.

34. The crank-handle and appendages differ somewhat from those of the Mark II 6-pounder. The cocking-toe projects upward. The crank-handle revolves freely on the stem, but in a boss on the outer side of the toe is a " runway " or slot (14a) in which plays a stud of the carrier (15). The " carrier " takes the place of the fly in the rock-shaft toe of other models and is an extra appendage. It is kept from turning on the shaft by a feather, and from coming off by the carrier-lock (16) (similar to the 6-pounder crank-handle lock). The runway in the cocking-cam is of such length that, in turning the crank-handle to the rear, the overrun permits the engagement of the two cocking-toes before the crank itself moves at all, and vice versa; the hammer is left undisturbed in closing.

35. The rock-shaft toe is upturned and moves to the rear in cocking. The rock-shaft catch is similar to that of the 6-pounder Mark II.

36. The stop-bolt works similarly to the 6-pounder Mark II, but the catch differs. It consists of a conical plug, having a spring extension, with a lug on its inner end that takes in the annular grooves in the stop-bolt hole. The catch lies parallel with the axis of the bolt,—a taper hole being cut through the head of the bolt.

37. As in the Mark II 6-pounder, there is no trigger; the free arm of the sear acts as such, the hook of the lanyard being attached to it. The extractor is in one piece.

38. The safety of the 6-pounder Mark I Hotchkiss breech mechanism lies in the following:

(1) *As to opening when fired.*—The block is held closed—first, by its own weight pressing down on the crank beyond its center; second, by the reaction of the crank-handles, the tendency being for them to fly forward; and third, by the small spring catch on the crank-handle toe seated in a notch in the gun.

(2) *As to firing before breech is closed.*—It is impossible to fire the gun—first, because the firing-pin would not be in line

with the primer; second, the cocking-toe would strike the cocking-cam before the firing-pin could attain its full throw, or reach the primer.

(3) *As to firing by shock in closing.*—It is impossible to do so, as the block slides along the cartridge head, and hence gives no blow, an advantage of the sliding-wedge system.

39. Plate III shows various guns to which the Hotchkiss system is applied; Figs. 1 and 2 show an old-style trunnioned 6-pounder built up with a tube and jacket which are held together by the *screwed* locking-ring (3), which also bears the front sight. Fig. 3 shows a 3-pounder of recent construction, trunnionless, with much longer jacket. Fig. 4 is an old-style 10-inch Krupp gun to which the sliding-wedge system is applied. This system, is of all types of breech closure, the most universally used and is employed in the navies and armies of nearly all nations. It is particularly a favorite with the Germans, for whom it is successfully applied to all sizes of guns by the Krupp factories. In the gun shown in Fig. 4, and usually in all main-battery guns, the block works horizontally instead of vertically, so that its weight may be more easily handled, and the mortise is kept as small as possible and is closed to the rear, leaving an aperture for loading. As may be seen, the system has the disadvantage of heaviness,—the block is heavier than that of most other systems and its housing must extend some distance to the rear, contributing greatly to the length and weight of the gun itself.

40. With each Hotchkiss gun in the U. S. Navy is furnished an *accessory box* containing:

(1) *Spare parts.*—Stop-bolt, hammer, firing-points, mainspring, sear, sear-spring, and an extractor.

(2) *Accessories.*—Sponge-brush, cleaning-brush, oil-can, combination dismounting-tool (a different kind is used for the two marks), dismounting-pin, monkey-wrench, hand-extractor (except for 1-pounder), drill-hook (for 3- and 6-pounder, Mark I), and lanyard.

CHAPTER XII.

GENERAL DISCUSSION ON GUN-MOUNTS.

Nomenclature.

1. The mount.—The entire system interposed between the gun and the structure of the ship, which serves to support the gun, secures it to the ship's structure, and provides for its elevation, train, recoil, and counter-recoil, shall be known as the *mount.*

2. The *mount* consists of the following parts:

(1) Stand.
(2) Carriage.
(3) Slide.
(4) Sleeve.

3. One or more of these parts are missing from mounts of certain types and, in those of other types, two or more are combined.

4. The parts are defined as follows:

(1) The *stand* is that part of the mount which is secured to the structure of the ship, and in or upon which the *carriage* rests and is moved in train.

(2) The *carriage* is that part of the mount, borne in or upon the *stand,* in which are the trunnion-seats; the *carriage* moves with the gun in train, but is fixed in elevation, the gun moving in elevation in or upon it.

(3) The *slide* is that non-recoiling part of the mount of which the trunnions form a part and in, through, or upon which the gun moves in recoil and counter-recoil; it moves with the gun in train and elevation.

(4) The *sleeve* is found in mounts of a few types only; it is rigidly secured to the gun and moves with it in recoil and counter-recoil in or upon the slide.

Application of the Nomenclature.

5. Turret-mounts.—

(1) *Stand.*—None; its place is supplied by the structure supporting the turret.

(2) *Carriage.*—The deck-lugs in combination with the turret itself.

(3) *Slide.*—In all, except the earlier hydraulic-return mounts, the sleeve encircling the gun to which the recoil cylinders are secured. In the earlier mounts the slide-rails on which the gun moves in recoil.

(4) *Sleeve.*—None in the later mounts; in the earlier mounts the part known heretofore as the saddle or cradle.

6. Pedestal mounts (so-called). (1) This class embraces all the 3-inch, 4-inch, 5-inch, 6-inch, and 7-inch mounts designed in the last seven years, and the application of the nomenclature needs no explanation. These mounts have no *sleeves.*

(2) In the earlier 4-inch mounts, the arrangement is the same as in the recoil mounts for minor-caliber rapid-fire guns hereinafter described.

7. Gravity-return mounts.—

(1) *Stand.*—The pivot socket and deck circles perform the function of a *stand.*

(2) *Carriage.*—None; the slide performs part of the function of the *carriage* as it moves in train with the gun.

(3) *Slide.*—The main part of the mount, usually called the slide, upon which the gun and the top-carriage (so-called) move in recoil.

(4) *Sleeve.*—The part heretofore called the "top-carriage;" this part combines the functions of a *sleeve* with certain functions of a *carriage.*

8. Non-recoil rapid-fire mounts.—These consist of *stand* and *carriage* only.

9. Recoil-mounts for minor-caliber rapid-fire guns.—

(1) In mounts designed for trunnion guns, the part sometimes called the "combined cylinder and trunnion-bearing" is the *sleeve* of the present nomenclature. The so-called "oscillating-slide" is the *slide.* The "saddle" and "saddle-pivot" are the *carriage.*

(2) In mounts for trunnionless guns, the combined sleeve and recoil cylinder is the *sleeve;* the other parts are as in other mounts.

10. Field-mounts.—

(1) The *stand* is the vehicle on which the gun is transported, commonly called the "field-carriage." It also performs one of the functions of a carriage, as it is that part which trains with the gun.

(2) The cylinder through which the gun recoils is the *slide.*

11. Stands may be "pivot-stands," "cage-stands," "rail-sockets," "port-sill sockets," "military-top stands," "boat-stands," "pillar-stands," "field-carriages," or any of numerous other special types.

12. In general, type-names, such as "turret," "pedestal," "port-sill," "military-top," "rail," "boat," "field," etc., are sufficiently descriptive of a mount, and the names of the several parts may be used without modifying words.

13. While nearly all mounts are now *hydraulic-recoil and spring-return,* there are still in service some "non-recoil mounts," "hydraulic-return mounts," and "gravity-return mounts," so that these terms must be used to give a complete description of a mount.

Discussion—Definitions.

14. The principal requirements of a modern gun-mount are: (1) safety under all conditions, which necessitates proper design and requisite strength of materials; (2) rapidity, ease, and smoothness of working; (3) durability; (4) simplicity; (5) gradual absorption of the shock of recoil and its dispersion over a sufficient area of the ship to prevent injury to the latter; (6) good control of the motive power, which, whether it be hand or other power, should be powerful and reliable; (7) provision for substituting hand-power, as far as practicable, if other motive power is ordinarily used; (8) interchangeability of parts of mounts of same mark.

15. All modern gun-mounts give the gun an arc of elevation of from 15° to 25° and the train is usually limited only by the form of the gun emplacement; mounts are conveniently divided

into classes according to the kind of recoil-mechanism used. These classes are (1) *non-recoil mounts,* (2) *hydraulic-recoil spring-return mounts,* (3) *hydraulic-recoil and return mounts,* and (4) *hydraulic-recoil and gravity-return mounts;* to which must be added (5) *field-mounts.* In all recoil mounts, means are afforded for returning the gun to battery, *i. e.,* its initial position; this mechanism usually *assists* in checking the recoil. In all but the smaller mounts, buffers of some form are provided for cushioning the counter-recoil. The gun recoils in line of fire except in mounts of class (4).

16. A non-recoil mount is one in which the gun cannot recoil except in so far as the elasticity of the metal permits; obviously, this class can be used only for very light guns.

17. A hydraulic-recoil spring-return mount (all modern mounts are of this class) is one in which the recoil is checked by hydraulic cylinders, closed and kept constantly filled with a "recoil liquid" (glycerine and water), the gun being returned to battery by the extension of spiral springs, also inside the cylinders, which are compressed during recoil. The cylinders are usually secured to a stationary part of the mount and the piston-rods to the gun, though in some mounts the reverse obtains. During recoil the pistons move along the cylinders and the recoil is checked by the friction of the liquid as it passes from one side of the piston to the other through apertures of variable area. The apertures consist of shallow grooves in the cylinder, not filled by the piston, and the variable area is obtained by tapering the width of the grooves, which finally disappear when the limit of safe recoil is reached; when the gun is in battery, the position of the piston is at the widest part of the grooves, which are from three to five in number. During the counter-recoil the liquid again passes over the pistons, aiding in controlling the counter-recoil. The counter-recoil springs surround the piston-rods, being held between the piston and cylinder-head under initial compression to keep the gun "in battery" as the ship rolls. Thus, when the recoil is checked, the springs are highly compressed and immediately shoot the gun out to battery. The counter-recoil is violent, and in large gun-mounts a "counter-recoil check" is fitted which may consist of spring buffers or of hydraulic checks. In the latter case, an extension of

the piston-rod beyond the piston enters a tapered hole in the front cylinder-head, or, vice versa, a rod projecting inward from the cylinder-head enters a tapered counterbore in the piston-rod, which hole, of course, fills with liquid at the beginning of the counter-recoil and acts in the same manner as the main cylinder, when the gun nears its position in battery.

18. A hydraulic-recoil and return mount, to which class the earlier turret-mounts belong, is one in which the recoil is checked as in Art. 17, the gun being returned to battery by hydraulic motive power. The recoil cylinders may be independent of the hydraulic system, or they may act also as motor-cylinders. In the first case, the recoil is checked exactly as in Art. 17, and the gun is returned by separate motor-cylinders, connected with the hydraulic system, whose piston-rods act on the gun-sleeve. In the second case, during recoil the piston-rods are driven *into* the cylinders, which are connected to the hydraulic system through check-valves at the opposite ends; during recoil these valves close and the cylinders act as in Art. 17, the water displaced by the piston-rods escaping through valves which are spring-weighted to the pressure of the hydraulic system. After recoil, the check-valves open and the hydraulic pressure, acting on the effective area of the piston-rods, returns the gun to battery; as this is done rather slowly, spring counter-recoil checks are sufficient. The 13-inch mounts of the Indiana are of this latter class, and the 12-inch mounts of the Texas of the former.

19. A hydraulic-recoil gravity-return mount is one in which the gun recoils up inclined rails *not* in the line of fire, the recoil being mainly checked by closed hydraulic cylinders acting as in Art. 17, and the gun sliding back down the inclined rails to its position in battery by force of gravity. The gun, by its trunnions, is secured to a movable part of the mount (comprising the cylinders), that slides on and is held to the inclined rails of a lower carriage; the piston-rods are secured to the lower carriage at the bottoms of the inclined rails. The counter-recoil is checked by spring buffers on the lower carriage. These mounts were fitted to the main-battery guns of our first steel ships, but are now obsolete and are no longer being fitted; the 8-inch turret-mounts of the New York are of this class.

20. A field-mount is one intended for shore use, and consists essentially of an axle mounted on two wheels, bearing a trail-piece with a small trail-wheel and a socket, to which is secured the gun-mount proper. Except for machine guns, which have non-recoil mounts, hydraulic-recoil spring-return mounts are used. Train is effected mainly by swinging the whole mount on its wheels; the elevating gear is fitted to the non-recoiling part of the mount. The general navy method is to carry ammunition on the gun-mount, as a combination of "limber" hooked to the trail of the mount is too heavy to be dragged by men.

21. A turret-mount is one in which one or two heavy guns of at least 6-inch caliber are mounted in an armored structure which is revolved on rollers by suitable machinery, the guns being elevated independently of the structure.

22. The training gear, hand or power, is the machinery that revolves the movable parts of the gun-mounts, to which parts it is secured in all except turret-mounts.

23. The elevating gear, hand or power, is that machinery secured to the carriage which, working on the breech end of the gun-slide, elevates or depresses the gun's muzzle. On firing, the gun's muzzle makes a violent effort to move in the vertical plane, describing a small angle which is called the *jump*. The gun being pivoted at its trunnions, the jump brings a strain upon the elevating gear, which is relieved of the shock by (1) spring buffers or by (2) friction-disks. *In the first method,* a worm which is indirectly secured to the carriage gears with an arc which is part of the slide; this worm works on its shaft by a feather, being capable of longitudinal motion along it and is supported from one end by a spiral spring surrounding the shaft. When the jump occurs, the worm is forced along its shaft and the spring takes up the shock without injury to the mechanism and returns the gun to its first position. In heavy turret-mounts, the same principle is applied in a different manner, and a hydraulic cylinder called the "dash pot" is associated with the spring. *In the second method* of controlling the jump, the gun-slide and carriage are connected by rack-and-pinion gearing instead of worm gearing. The elevating pinion is not secured directly to its shaft but is held to it by friction-disks which *are* so secured and connect the pinion on the shaft by friction

alone. When the jump occurs these disks permit the pinion to slip around the shaft, as long as the elevating-arc puts sufficient pressure on its teeth, and thus cushions the shock. In this latter method the gun will not return to its former position, but will usually be somewhat elevated after firing; this is a disadvantage, but since the spring method violently strains the connecting parts, the friction device is preferred.

Metals used in Gun-Mounts.

24. Gun-metal is commonly used for most parts of 6-pounder and smaller mounts. For larger mounts this metal is not reliable, particularly for the large parts, such as the pivot-stand, saddle, etc., for which parts cast steel of good quality is used. The castings are made by private contractors and, after being tested, inspected, and passed upon by the government inspectors, are sent to the Naval Gun Factory, at Washington, D. C., where the parts are machined and assembled. The principle in designing is to avoid having steel on both sides of a working surface; this is accomplished by making one of the parts of gun-metal, if small, or, if both parts are large, by bushing one of them with it. For example, the insides of the sleeve and trunnion-seats are so bushed in recent mounts and the pistons of gun-metal work inside cast-steel recoil cylinders.

CHAPTER XIII.

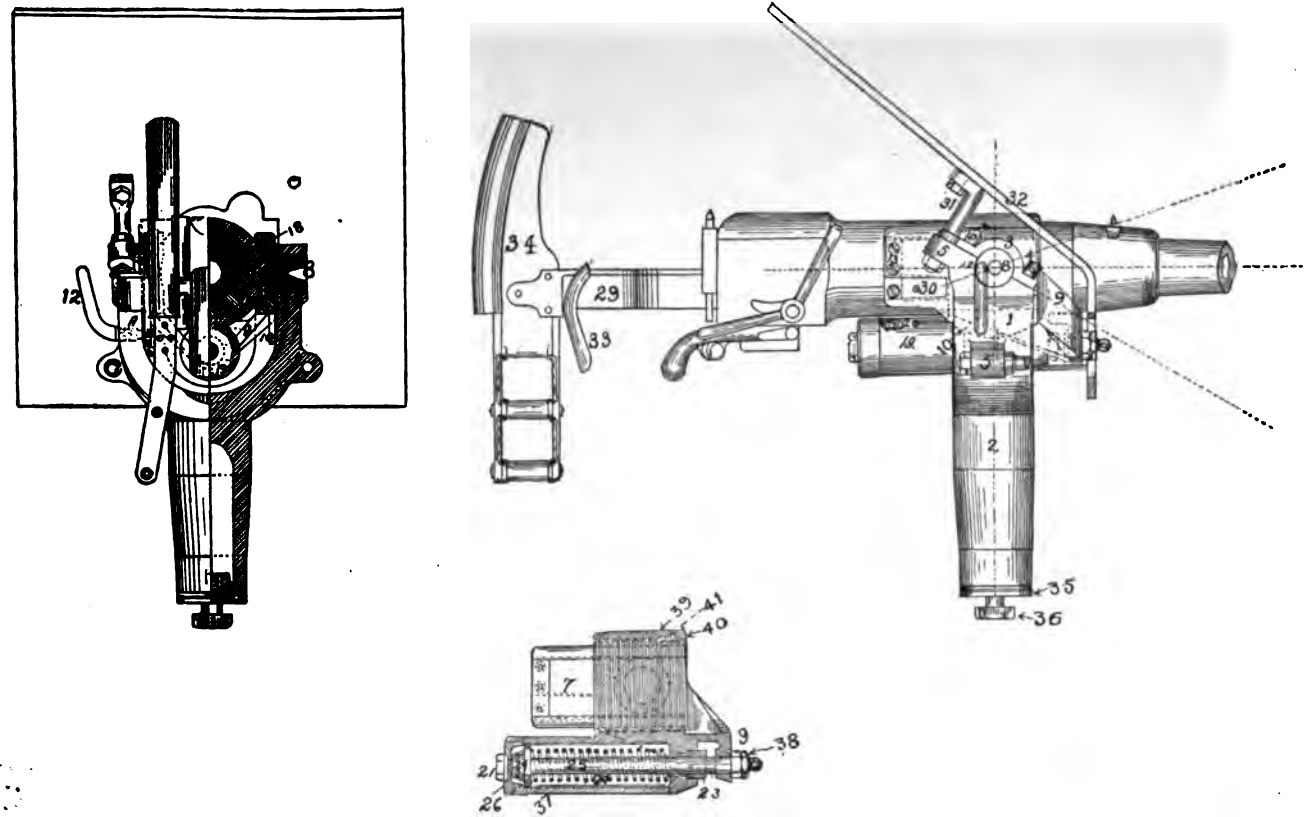
MOUNTS FOR SECONDARY-BATTERY GUNS.

6-pounder Mount, Mark III.

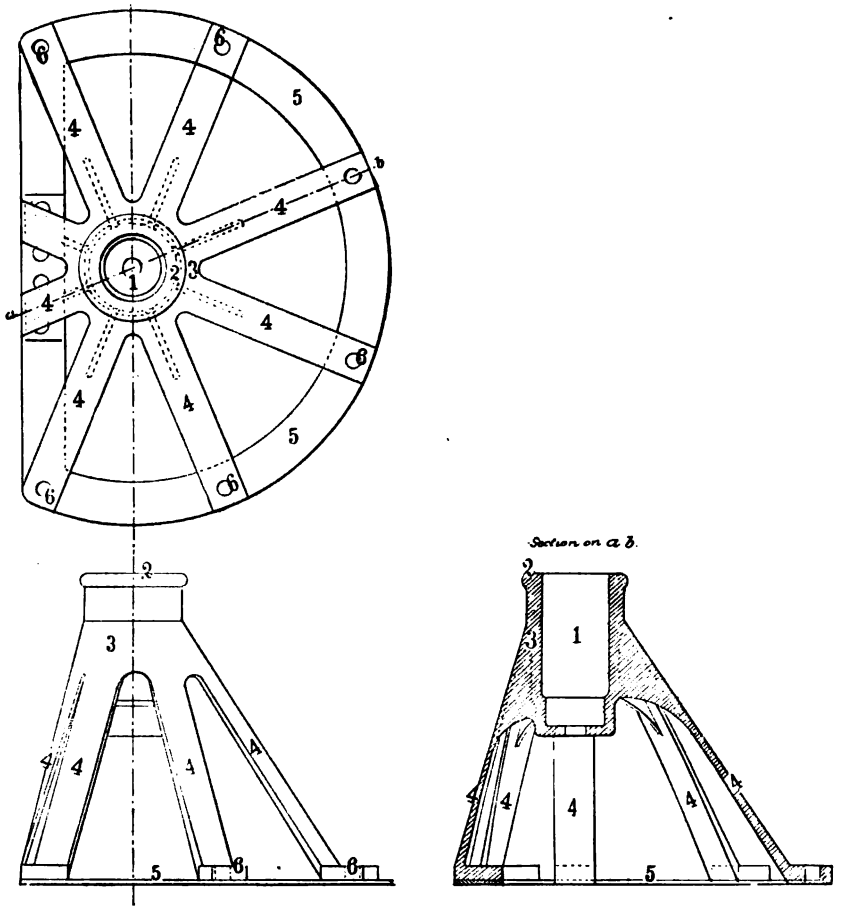
1. The Mark III mount is a hydraulic-recoil spring-return mount for trunnionless R. F. 6-pounders, in which the recoil cylinder and sleeve, with which it is combined, recoil with the gun, the piston-rod being secured to a stationary part of the mount; the principal parts, with the exception of the cage-stand which is of cast-steel, are machined from bronze castings. The mount shown in Plate I is adapted for Hotchkiss R. F. 6-pounders; with the exception of a different form of shoulder-bar secured to the *right* side of the slide, the mount for trunnionless Driggs-Schroeder R. F. 6-pounders is in all respects the same (see Plate III).

2. The sleeve (17) and **recoil cylinder** (19).—The gun, which is threaded on the outside, screws into the sleeve (17) and is secured by the key (40) inserted from the forward end. Suitable surfaces for fitting into the slide-guides (16) of the slide are machined on each side of the sleeve. Cast in one with the sleeve is the recoil cylinder (19), closed at its rear end by a bonnet (21) and having at its forward end a stuffing-box (23), through which the piston-rod (25) passes. Upon the inside surface of the cylinder are cut the recoil-grooves (37), three in number, which taper rapidly from a wide opening at the normal position of the piston to nothing at the limit of recoil. The cylinder is filled with the recoil liquid through the plug (20). The piston-rod, secured by locking-nuts at its forward end to the slide-transom (9), carries the piston on its inner end. The counter-recoil spring (27) is held in a state of initial tension between the front cylinder-head and the piston; there is no counter-recoil check.

3. The slide (7) (formerly called "oscillating slide") is fitted with trunnions (8) which rest in the trunnion-seats of the



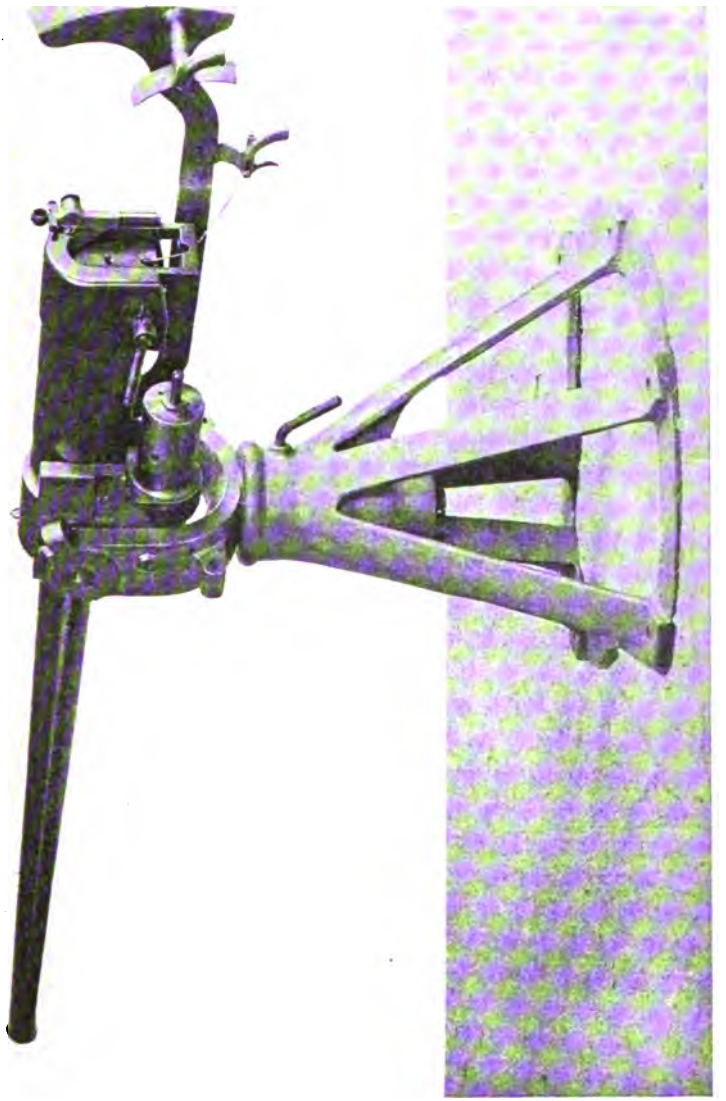
HYDRAULIC-RECOIL MOUNT FOR 6-POUNDER D.-S. AND H. GUNS, MARK III.



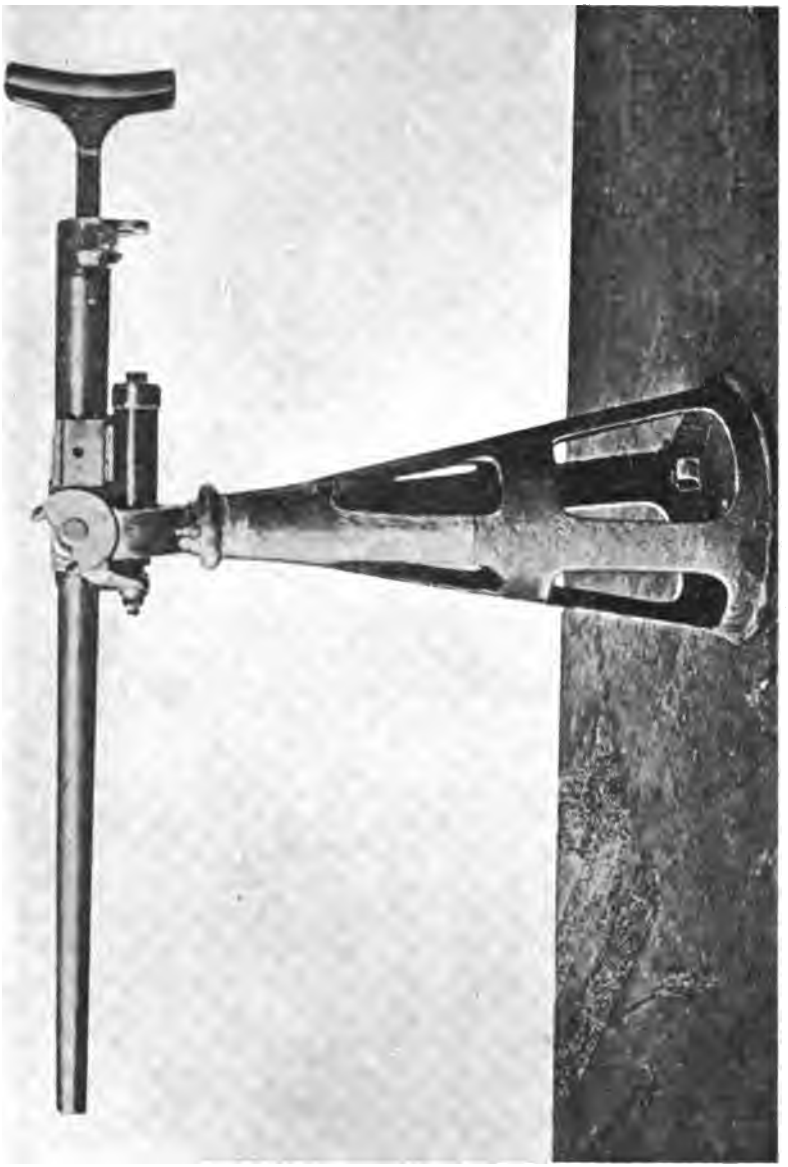
STEEL CAGE-STAND FOR 3-POUNDER AND 6-POUNDER RAPID-FIRING GUNS.

Nomenclature.

1. Pivot-Socket. 2. Cage-Head. 3. Cage-Body. 4. Cage-Legs. 5. Cage Deck-Plate. 6. Cage Deck-Fastenings.



DRIGGS-SCHROEDER 6-POUNDER RAPID FIRING GUNS.



DRIGGS-SCHROEDER 1-POUNDER RAPID-FIRING GUN.
ON RECOIL MOUNT.

carriage (formerly the "saddle") and are there secured by the cap-squares (3). The slide-transom (9) connects the two sides of the slide and affords a non-recoiling place for attaching the piston-rod. The recoil-stops (13) are secured by screws to the rear ends of the slide-guides, at the extreme limit of recoil, The shoulder-bar (29), by which the gun is pointed in train and in elevation, is dovetailed to the left outer part of the slide; the gun-pointer grasps the handle at the lower end of the bar and rests his shoulder on the rubber buffer (34); the deflector (33) throws the ejected cases downward.

4. The carriage (formerly the "saddle") (1) is a Y-shaped casting having the trunnion-seats on its arms and the pivot (2) forming its lower part. The shield (32), a ½-inch forged-steel plate, is, when used, secured to the lugs (5) by the shield-supports (31). The slide-clamp (12) passes through the carriage, and, when set up, bears firmly against the slide, locking the two parts together. The surfaces of the *pivot* (2) are accurately machined to fit the socket of the stand; the securing-bolt (36) is inserted through the bottom of the socket from beneath and screws into the lower end of the pivot. The weight of the gun and movable part of the mount rests directly upon the bottom of the socket through the frictionless-washer (35), which contributes to ease in training.

5. The stand (Plate II).—The *stand* for a gun mounted on the rail is simply a socket built into the rail; for a gun mounted on deck, a cage-stand as shown in the plate is used. The stand is secured to the deck by eight bolts through the deck-plate (5), and the pivot rests in the socket (1). The pivot-clamp (not shown) screws through the top of the stand, and, when set up, bears firmly against the pivot and locks the two together.

6. All recoil mounts for 1-pounders are similar to the above; Mark I and Mark II mounts are designed for trunnioned R. F. guns, and, except in the mode of securing the gun to the mount, are similar to the above Mark III mount (see Plate IV).

CHAPTER XIV.

3-INCH AND INTERMEDIATE GUN-MOUNTS.

3-inch Mount, Mark III. (See Plate I.)

1. The mounting resembles a Mark III 6-pounder mount to which is added a geared elevating device; the main difference is that the gun recoils through a sleeve (which is now termed the "slide"), drawing the pistons through the recoil cylinders, which are stationary, whereas in the 6-pounder mount the "sleeve" is a part of the gun and recoils with it through the "slide." The principal parts are: the *slide* including the recoil cylinders; the *carriage;* the *elevating gear;* the *stand.*

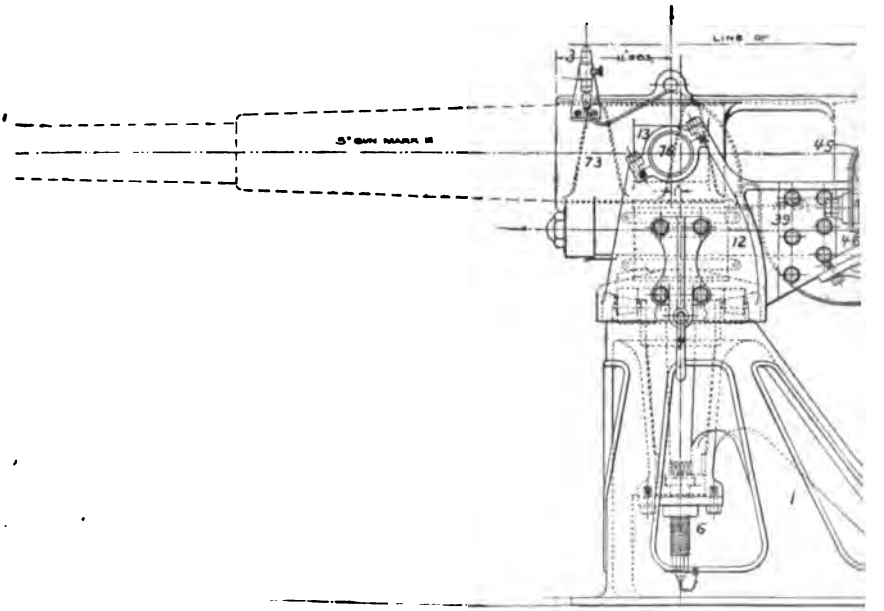
2. The slide (73), of cast steel, is cast in one with the two recoil cylinders; a large hole on each side in rear of the trunnions is for lightness; the whole inner surface, on which the gun slides, is bushed with bronze—in the bushing are cut spiral oil-ways. The gun has ribs on top and bottom which fit wide longitudinal grooves in the slide and prevent the gun from turning. There is a lifting-eye on the top of the slide which is directly in line with the trunnions (76); the latter are bushed with bronze, as are all the working surfaces. The elevating-arc (53) is bolted to a heavy projection, on the left rear side, in which is machined the box for the sight (3); the front sight is also secured to the slide (the sights shown are night sights,—the wires are shown leading to the battery-box on the right side). The two hydraulic recoil cylinders (79) are rifled as heretofore described,—the ends are closed by bonnets. The cylinders are filled through the holes (78) which are in line with the equalizing-pipe (77) which connects the two cylinders and makes the pressure, during recoil, uniform; the recoil-liquid may be removed through the plugs (71). The piston-rods (89), with the pistons (88) on their forward ends, pass through stuffing-boxes in the rear bonnets and are secured by heavy nuts to a steel yoke (2) around the breech of the gun. The

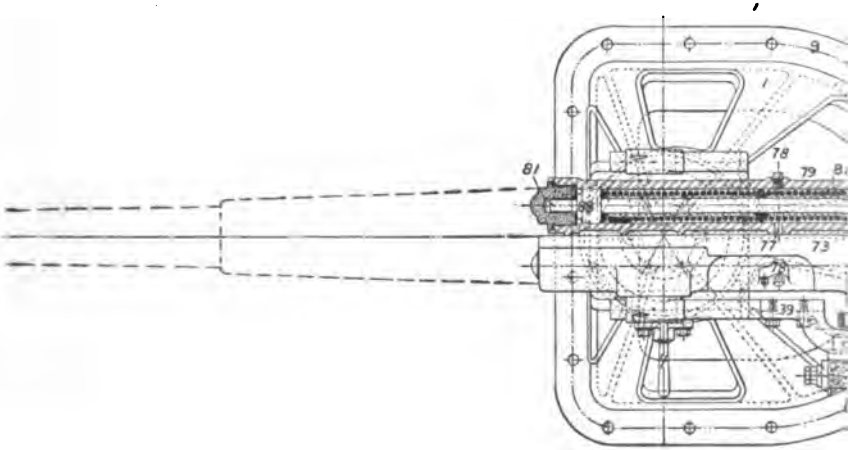
counter-recoil springs (85) are each in two sections separated by disks; they are assembled under initial tension and hold the gun in battery. The counter-recoil check (81) is a device in each cylinder which cushions the counter-recoil in the same way that the cylinder checks the recoil—by the friction of the liquid in passing a small orifice. The piston-rod projects through the piston and at the end of the counter-recoil enters a tapered hole in the front bonnet and forces out the liquid.

3. The carriage.—The trunnions are held in the carriage (12) by cap-squares (13). The *pivot* (5), a part of the carriage, fits the cavity of the stand only at top and bottom, where the surfaces have bronze bushings. The entire upper mounting may be raised by the lifting-screw (6) working through a bronze cap bolted to the stand; the screw also holds the parts together. Friction in training is reduced by the conical rollers (8) through which the weight of gun and upper mounting rests on the stand. The rollers are spaced by floating-rings on their axles; their upper and lower paths are separate steel pieces set into "carriage" and stand. The rollers may be removed for cleaning and lubrication by raising the carriage a few inches by means of the lifting-screw (6). The pivot-clamp (4) sets up to the stand, through a lug on the carriage.

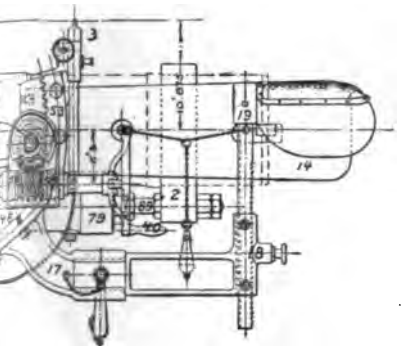
4. The elevating-bracket (39), a part of the carriage, bears the training and elevating mechanism. It has been decided that the 3-inch gun is not too large to be *trained* by a shoulder-bar on the carriage. To point the gun in *elevation* in the same manner, however, would involve fitting the bar to the slide and the gun is too heavy and the shock of recoil too great for this; besides, a gun may be pointed more accurately by gearing, and it has been proposed to give even smaller guns regular elevating gears. The shoulder-bar ships in a socket in the projection (17) of the elevating-bracket. An upright (19) bears the shoulder-piece which the gun-pointer holds under his right arm-pit; as may be seen in the plate, the shoulder-piece may be adjusted and secured at the most convenient height by the clamp (18). To keep the pointer from leaning against the gun and being injured by its recoil, the brass guard-plate (14) is bolted to the slide.

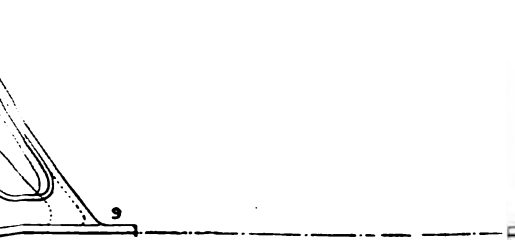
5. The elevating wheel (40) turns a horizontal shaft on which

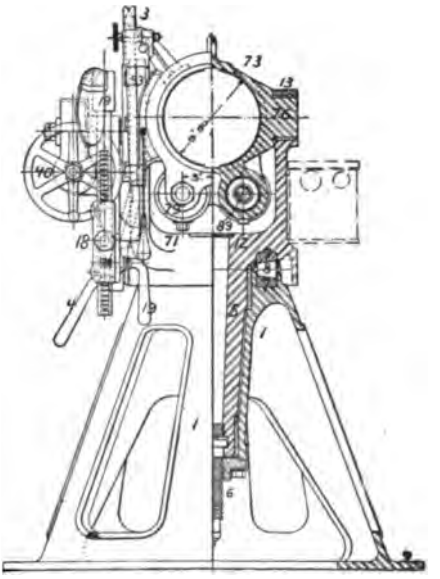


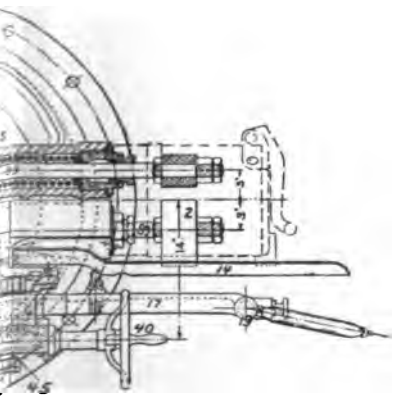


3-INCH MOU

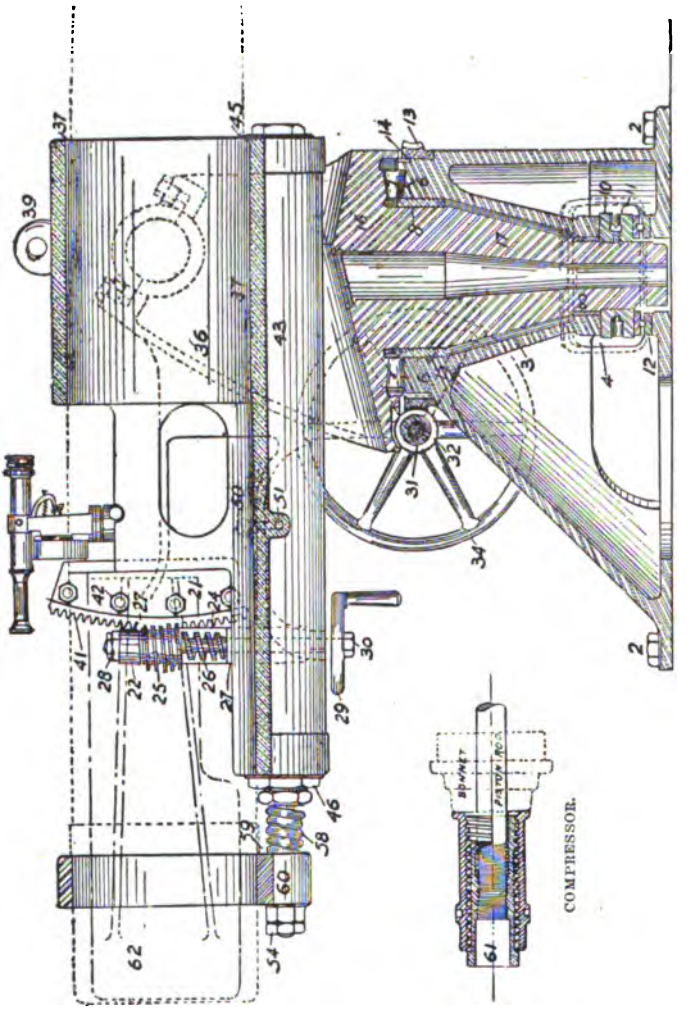




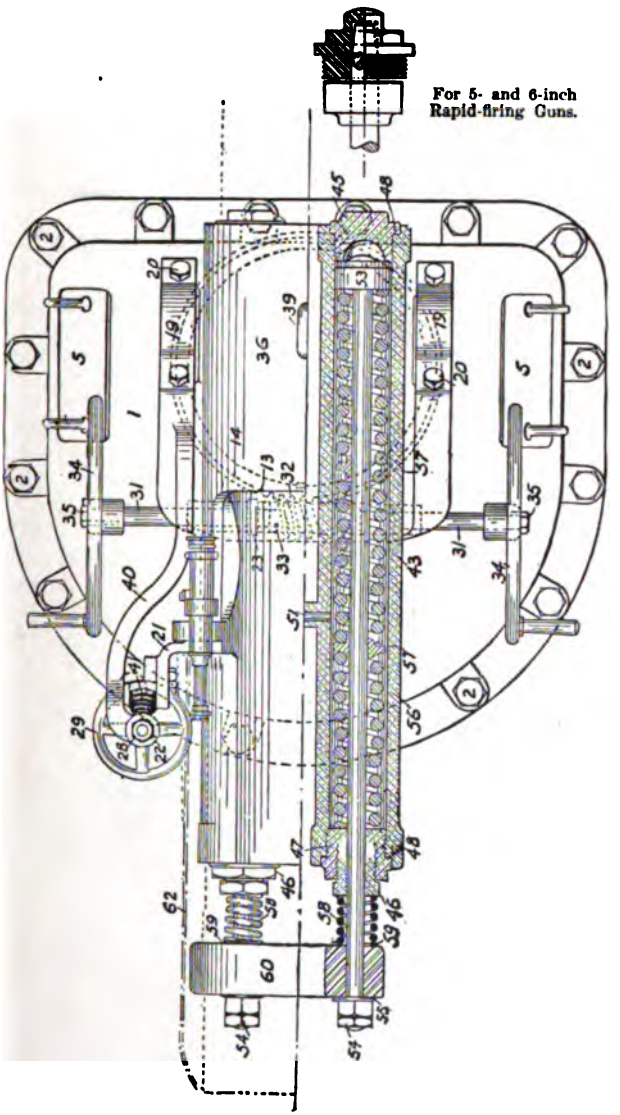




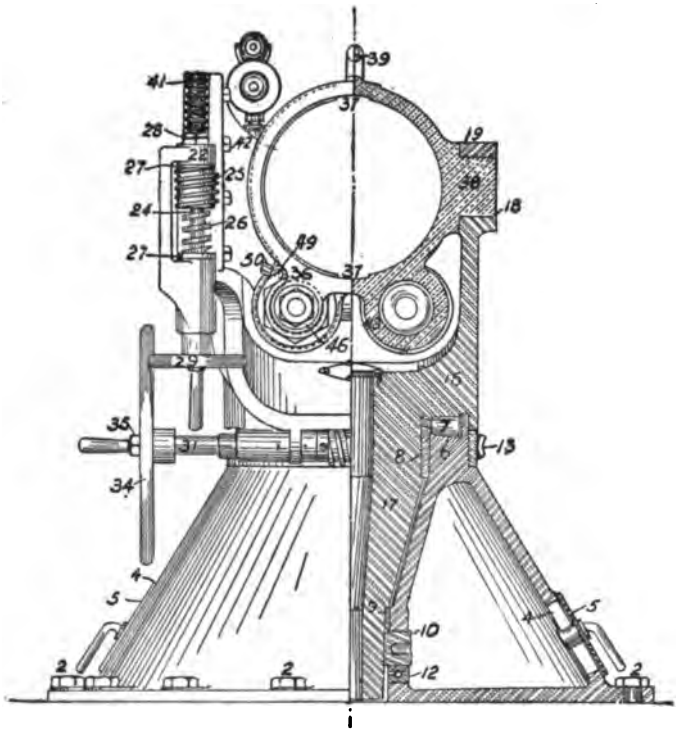
NT, MARK III.



PEDESTAL MOUNT—4-INCH RAPID-FIRING GUN.



PEDESTAL MOUNT.



PEDESTAL MOUNT.

a worm (46) is held between two frictionless washers (59). The worm gears with a worm-wheel on the cross-shaft (45), on the other end of which is a pinion gearing in a rack on the *concave* side of the elevating-arc; it has been found that the strain on the elevating gear during firing is greater if the rack is cut on the convex side. To cushion the jump, the worm-wheel is held between friction-disks on the cross-shaft (45) instead of being directly secured to it.

6. A few 3-inch mountings of this type were originally built with geared training as well as elevating devices; others, built on the design shown in the plate, have since been altered to use a separate trainer and a sight fitted for his use. It is likely that all these mounts will be refitted to use telescope sights.*

7. The stand (1), of cast steel, is designed with a view to lightness; in other services, cone-stands, without lightening-holes, are largely used for secondary-battery guns. The inner portion of the stand is supported by deep webs running out to the legs of the cage; the entire mounting is secured to the deck by bolts through the deck-circle (9).

"PEDESTAL" MOUNTS. (See Plates II, III, and IV.)

8. These mounts were so named because of the pedestal form of the stand, which permits mounting the gun close to the side, thereby keeping down the size of the straight gun-port for a prescribed arc of train. All mounts are now designed to this end and are "pedestal" mounts, but it was formerly not the case, and the center of motion in training used to be much farther from the gun-port. To obtain a fair arc of fire, the port then had to be circular, or very large, and guns were mounted in *sponsons;* these latter project inconveniently from the side, are expensive to build and their use has been abandoned.

9. The pedestal mounts for 4-inch, 5-inch, and 6-inch R. F. guns are similar in their principal features; the one shown in the

* All 3-inch mounts are now (1905) being fitted with cross-connected telescope sights, see Chapter XXI. There is a training wheel on each side and on the left side there is an elevating wheel working in the vertical plane parallel to the gun's axis.

plates is for a 4-inch gun and is a fair example of the class. Since it was designed, many changes have been made in the sights and pointing mechanisms and although many similar ones are still in service they have been altered so extensively that the character of the mount has changed. This one is given as originally designed and its unsuitableness under modern conditions is pointed out below.

10. The slide, recoil mechanism, carriage, and stand are, in general, like those of the recently designed 3-inch mounts. The *bronze slide* did not extend far to the rear and has in some cases proved too weak; hence a strengthening-band running from the elevating-arc over the gun to the opposite recoil-cylinder has been added. The counter-recoil is cushioned by buffer-springs (58); in the 6-inch, and in most of the 5-inch mountings, dash-pot checks in the forward bonnet are employed instead. The outside of the stand is solid in all mounts of 4-inch and larger guns. The nut (10), screwed on the lower end of the pivot, serves to lock the carriage to the stand or to raise it, giving access to the rollers (7); to do this, remove the watertight doors (5), insert heavy rods into the holes (11) in the nut and turn it in the proper direction—after removing the set-screw. The frictionless-washer (12) is interposed between the nut and the deck-plate of the stand to facilitate the operation.

11. All main-battery guns are trained by gearing; the training-rack (13) is secured to the stand—a general rule followed in all types of mounts. The training-shaft (31), turned by hand-wheels, rests in bearings on the carriage and its worm engages the rack. The elevating-shaft (24) of the 4-inch mount is vertical and carries a worm (25) which gears in a worm-rack (41), cut on the *convex* side of the elevating-arc. The worm is loose on its shaft, but is constrained to turn with it by a feather; it is held upward in position by a spring (26) which permits it to slip downward, cushioning the jump as the gun is fired, and then forces it back to its former position.

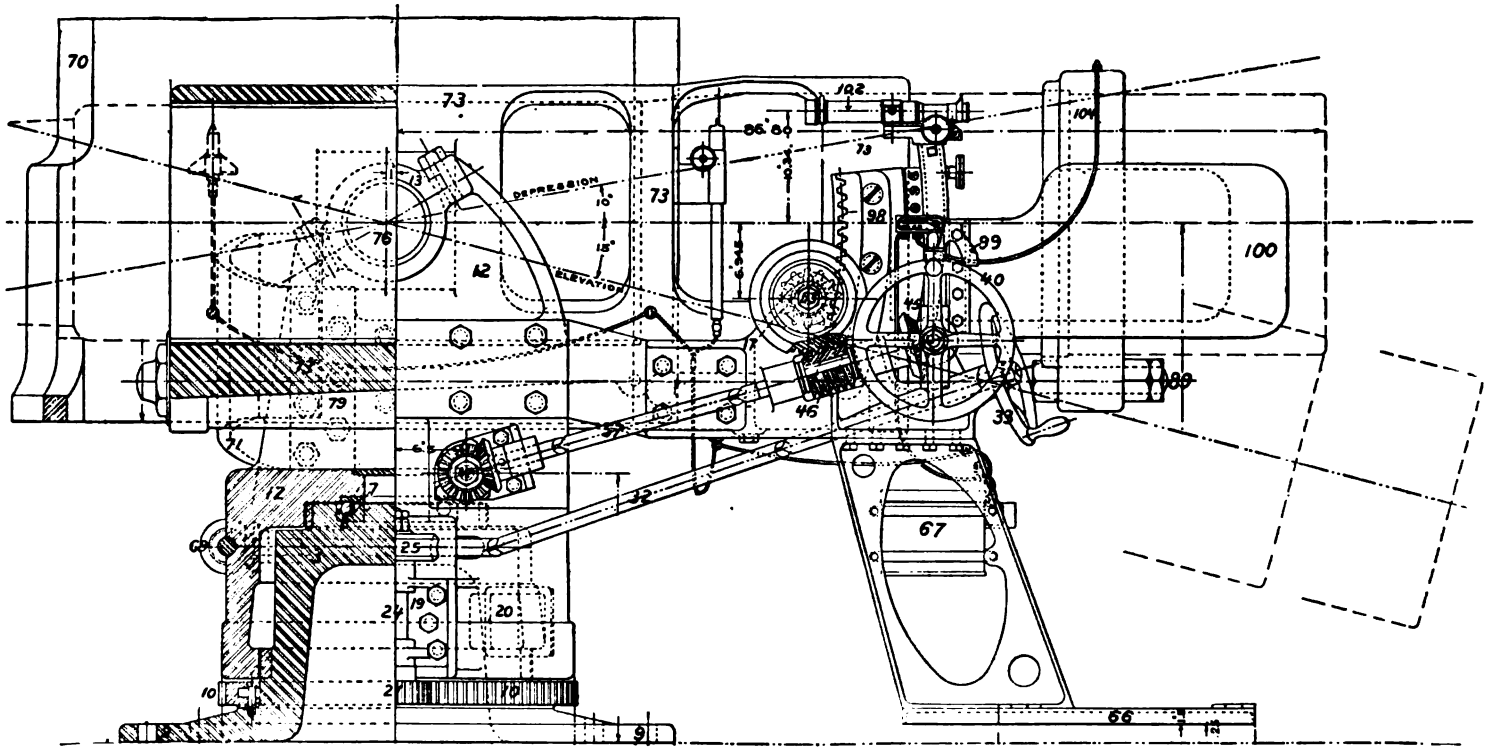
12. At the time the first pedestal mounts were designed, it was intended that the gun-pointer should do all the work of pointing, sight-setting, and firing. To this end, the elevating and training gears were arranged on several different plans, all of

which placed the two hand-wheels within reach of the pointer at the sight on the left side; one plan placed the elevating-wheel on a sleeve around the training-shaft and the two wheels were concentric and close together, making it impossible to work both at once and at the same time be ready to fire. It was found, at about the same time in other services, that the best results are not obtained in this way and that pointing in elevation, and firing, are quite enough for one man. In the division of duties, the *trainer* has to do solely with lateral pointing,—he may work from the left side, conned by the pointer, or he may use the training gear and sight on the right side. Good results may be obtained in either way, but we now prefer to give the trainer a sight and training-wheel on the right side.

13. Under the modern requirements, in which the sights are to be held on the target throughout a string of shots, fired while the ship is rolling, the pointer has the most difficult and fatiguing duty, and the elevating-wheel should be placed advantageously for him. With it fitted as in Plate II, it is nearly impossible to maintain a " continuous aim " for any length of time. The proper place for the elevating-wheel is a little below the pointer's shoulder with its plane vertical and nearly parallel to the vertical plane through the axis of the bore; all future mounts will fulfill this condition; those pedestal mounts otherwise constructed are being rapidly converted. The installation of the training-wheel is not of so great importance, but any hand-piece, which controls the pointing of a heavy gun, needs great leverage to obtain the delicate movements required.

14. In the future, the elevating and training gears will be installed as follows:

Size.	Elevating-arc.	Elevating-wheel.	Training-wheel.
3-inch.....	Left side.	Left side.	Both sides.
4 "	" "	" "	Right side.
5 "	" "	" "	" "
6 "	Both sides	" "	" "
7 "	" "	" "	" "


70
73
102
104
86
84
13
DEPRESSION
10°
15°
ELEVATION
73
92
99
100
40
76
42
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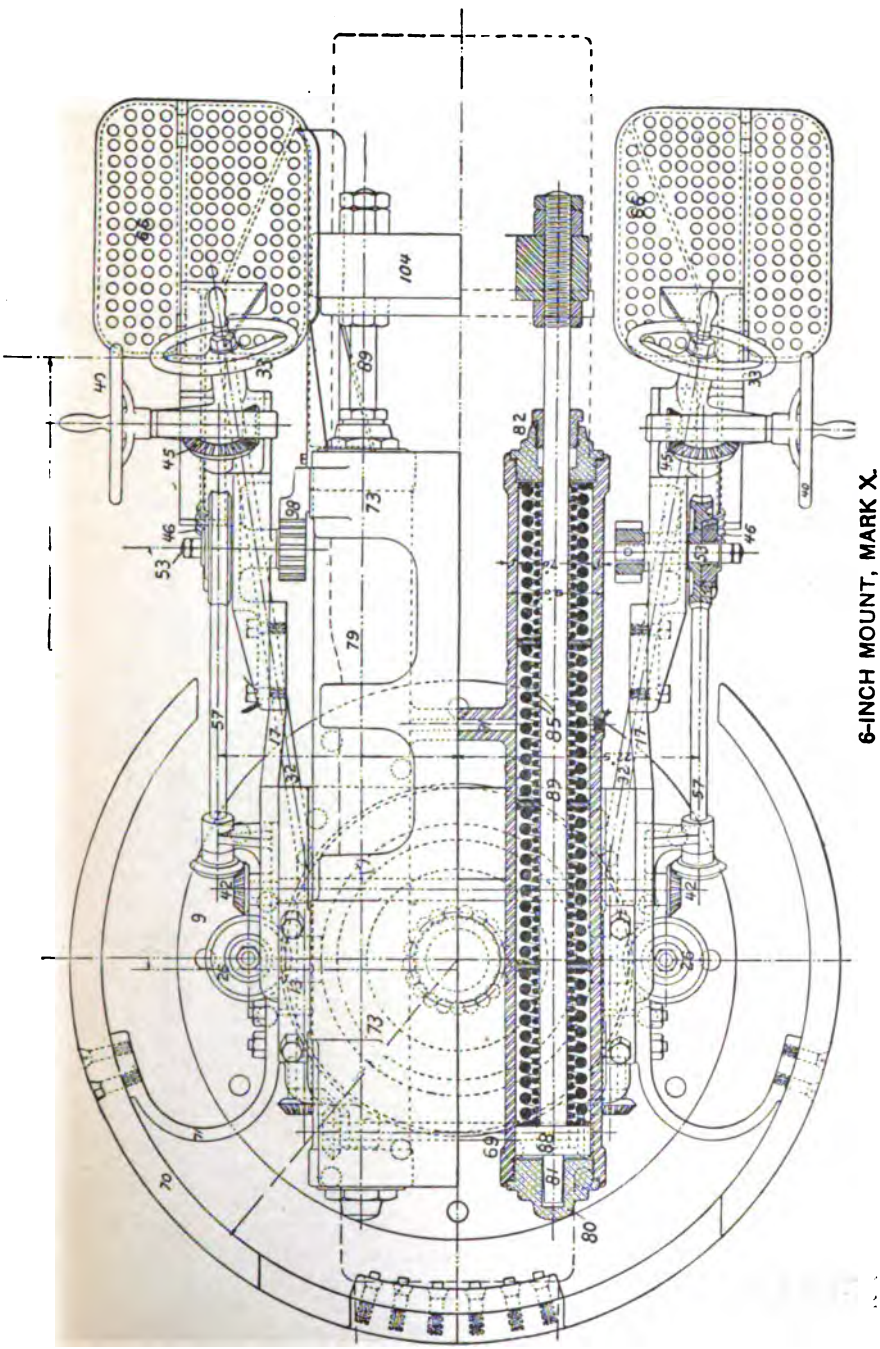
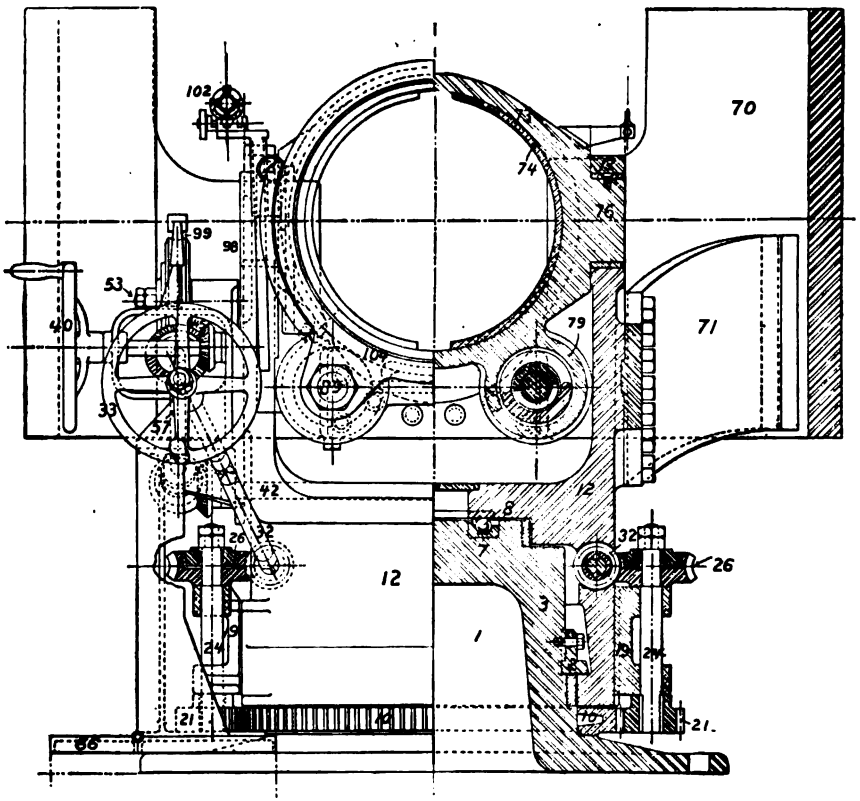
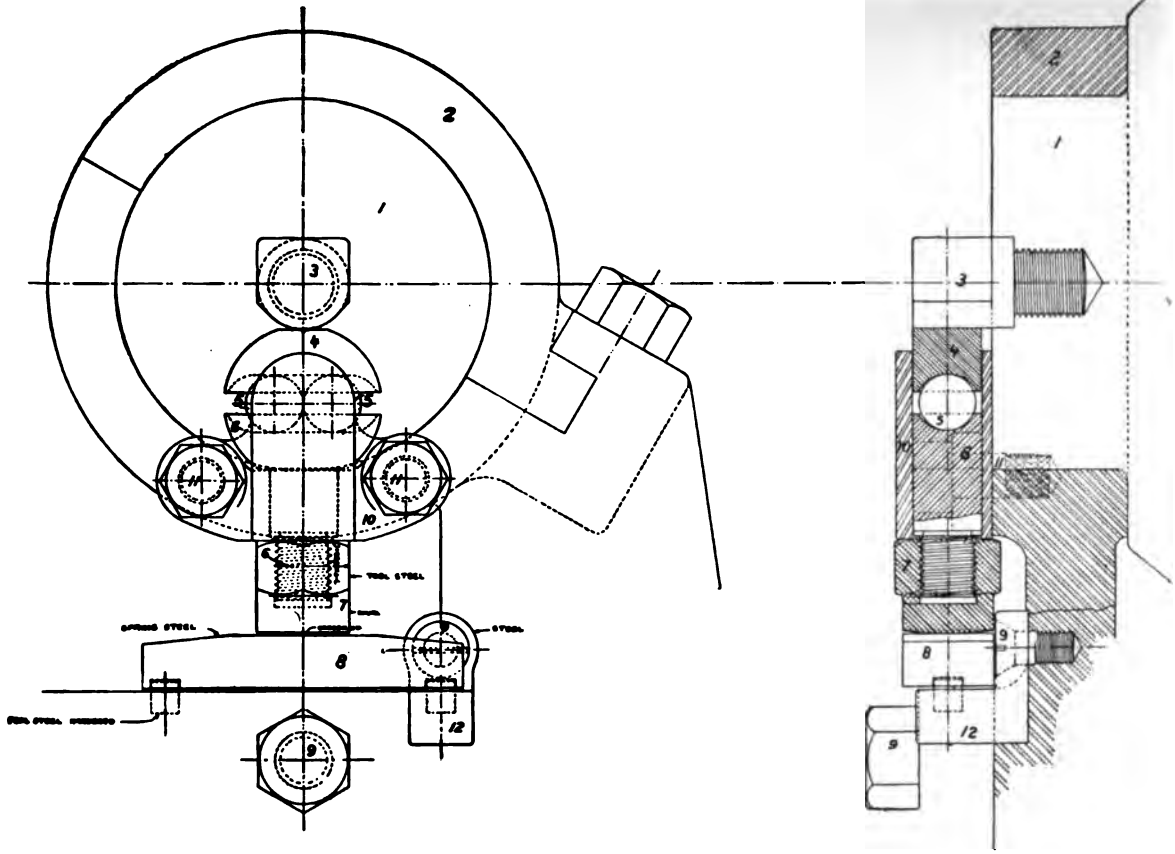


6-INCH MOUNT, MARK X.



6-INCH MOUNT, MARK X.
Rear View.



Side View

Section through Center.

FRICTIONLESS TRUNNION DEVICE.

15. A compressor, for use in dismounting or assembling recoil cylinders, is supplied to all ships (see Plate II). In dismounting, detach the gun from its piston-rods and run it in out of the way. Screw the compressor on the end of the piston-rod until it brings up against the rear bonnet of the cylinder. Then an inner sleeve, which has engaged the thread on the rod, is screwed to the rear by a threaded shaft and brings the rod with it, compressing the springs. When the piston is clear of the forward cylinder-bonnet, the latter may be removed; the compressor is then worked backward, easing the piston-rod through the cylinder until the springs are fully extended, whereupon the compressor is removed and the recoil mechanism withdrawn.

6-INCH MOUNT, MARK X. (See Plates V and VI.)

16. This mount, constructed for the Maine and class, is designed to meet modern requirements. It is to be noted that: (1) Ball-bearings instead of rollers are employed; (2) the trainer and pointer stand on platforms hung from the carriage instead of having to walk along the deck as the gun is trained; (3) the carriage is not formed into a pivot which fits a socket in the stand, but embraces it as a huge collar fitting around it.

17. The slide (73), recoil, and counter-recoil mechanism is like that of the 3-inch mount; the counter-recoil springs are double, divided by disks into four sections in each cylinder. There is an elevating-arc (98) bolted to the slide on each side; the three sets of sights are also secured to the slide; in Plate V, the night sights are shown on the left side with the leading wires connected to the firing battery (67).

18. The carriage and stand.—The upper part of the carriage (12) is of the usual form; an elevating-bracket (17) is bolted on each side; they support the pointing gear, the firing-key (99) and the platforms (66). The lower part of the carriage is socketed over the stand; the two vertical bearing surfaces, rings at the top and bottom, are bushed with bronze. The ball-bearings (8) travel on top of the stand in a hard forged-steel *ball-race* and an upper *ball-race,* also of hardened steel, is set into the carriage. The cast-steel stand (3) is a short thick column held to the deck by

bolts through the deck-circle (9); the training-rack (10) is secured to the stand.

19. The vertical training-shafts (24) turn in bearings in lugs (19) bolted to the carriage. They bear pinions (21), gearing in the rack, and worm-wheels (26) which are turned by worms on the training-shafts (32); the latter, turned by hand-wheels (33), have bearings in the carriage and are cross-connected by the shaft (69), through bevel gearing. Knuckle joints are placed in the four elevating and training-shafts.

20. Elevating-shafts.—Turning in bearings in each elevating-bracket, is a horizontal elevating-shaft (53) which has at one end a pinion, gearing with the elevating-arc, and holds a worm-wheel between friction-disks at the other. These worm-wheels are turned by worms (46) on the elevating-shafts (57), which are connected to each other by the cross-shaft (42) through bevel gearings; they are turned, through similar gearing, by the hand-wheels (40) working in the vertical plane. Ball-bearing frictionless washers are interposed between the ends of all four worms and their thrust bearings.

21. The training worm-wheels (26) are not rigidly connected to the vertical training-shafts but are held to them by a friction device as shown. As at first built, the elevating-worms had the same device, but this has since been altered. For the elevating gear, the frictional surface, was too small, and great pressure was necessary, or the gun would fly up inconveniently at each shot. So a "multiple disk" device has been substituted in which six brass disks keyed to the shaft enclose a like number of steel disks keyed to the elevating worm-wheel. A much greater surface is thus obtained and the pressure between the disks need not be great.

22. The later mounts of this type have, in place of the ball-bearing device fitted to Mark X mounts, a "two point" ball-bearing designed by Lieut. H. W. Jones. The balls are placed on a ledge at the upper corner of the stand; the weight of the carriage etc., rests on them in the same manner and they also take the thrust of the mounting when the ship becomes inclined. The sides of the carriage fit over the balls very closely and the upper bronze bearing-ring of the Mark X mount is thus replaced by a bearing as nearly frictionless as possible.

Gun Shields.

23. In addition to the stationary armor around the gun emplacement, the gun is protected by a 3-inch cylindrical shield secured to the carriage by the U-shaped brackets (71); the latter are arranged to give as much cushioning under a blow as possible. The shield, training with the carriage, is concentric with the mount and completely closes the gun-port. The only opening is the port through the middle of the shield, which is only sufficient to permit the gun to be elevated through its prescribed arc and give the pointer an opening to see through. Shields of various forms, designed to protect the mounting and gun-servants from small projectiles, are in many cases supplied to unarmored ships as well. They are built on the deflective system with the thickest portion normal to the line of fire; obviously, shields must be attached to the carriage.

Frictionless Trunnion Bearings. (See Plate VII.)

24. We have seen how friction in training is greatly reduced by suitable bearings; the same weight, less that of the carriage, has also to be moved in elevation and, since a great deal of elevating is required in maintaining a "continuous" aim, an arrangement that will minimize friction at the trunnions is also needed. A device which utilizes spherical rollers has recently been adopted and will be fitted to all intermediate mounts.

25. A small supplemental trunnion (3), with rounded lower side, is screwed into the slide-trunnion (1) which is held to the carriage by an ordinary cap-square (2). The small trunnion bears on a shelf (4) which in turn rests on two hard steel balls in a shallow trough (6), which is supported from the carriage. While the gun is being worked, its weight is to rest on the shelf (4) which is moved back and forth on the rollers by the motion of (3), the lower side of which is *not* at the center of rotation of the trunnion,—as may be seen in the plate. The carriage and cap-square embraces the slide-trunnion closely and, when the gun is fired, the elasticity of the parts of the frictionless device permits most of the shock of recoil to be received by these heavier parts.

26. The trough (6) rests on an elastic steel bar (8) which is

secured to the carriage by lugs (12) and tap-bolts (9). The trough is held from turning or falling outward by a bracket (10) secured to the carriage by bolts (11). The height of the shelf must be such that all the weight rests upon it; the adjustment is made by the nut (7) which raises or lowers the trough by its support. In making the adjustment, the rule is to raise the shelf until a thin piece of paper can be inserted under the slide-trunnion —about the same space should be left all around it. In the first mark of the device the adjusting-nut is often somewhat inaccessible. In the latest form a part of the trunnion (3) is the adjustable part; the troughs of the mark are longer and four balls are employed in place of two. Another device, that came into use several years ago, the "knife-edge" trunnion, will be described in a subsequent chapter.

CHAPTER XV.

10-INCH TURRET-MOUNT, MARK II.

1. The Mark II turret-mount, usually called the hydraulic turret-mount, is a hydraulic-recoil and return mount in which one cylinder serves to check the recoil and to return the gun to battery; all the gun-working machinery, except the turning engine, is actuated by hydraulic power. The 10-inch and 12-inch guns of the monitors Monterey, Monadnock, Amphitrite, and Puritan are installed on this type of mount, as are the 13-inch guns of the battleships Indiana, Massachusetts, and Oregon; the description is written for the Indiana. (Plates VII and VIII give the general arrangement of a turret containing two 10-inch guns.)

2. The hydraulic systems of the two turrets are connected, and power at 600 lbs. pressure is maintained in the piping by powerful steam pumps located below the armored deck. Each turret has its own magazines and shellrooms, which are under the charge of the turret officer, opening into a handling-room from which the hydraulic hoists convey the ammunition to the guns.

3. The turntable, or main foundation for all the revolving parts of the turret, is built up of steel plates and angle-irons and is arranged to rotate on live rollers (67) which travel on a roller path (68) built into the barbette structure well inside the armor; the rollers are spaced by floating-rings secured to their axles. The weight of the revolving part of the installation, about 490 tons for 13-inch guns, rests upon these rollers and the horizontal thrust of the guns in recoiling is transmitted to the ship by their flanges. The circular barbette (69), 17 inches in thickness, extends from the armored deck well above the turntable, while the guns and upper parts of the mountings are protected by a 15-inch vertical-sided turret, resting on the turntable and extending a little below the top of the barbette. The turntable is revolved by a two-cylinder steam turning-engine in a compartment directly

below the handling-room; hand-turning gear, which can be connected only after disconnecting the engine, is fitted in the same compartment. The pinion of the training shaft, which is actuated by the turning-engine through connecting shafting, gears in the circular training rack of the turntable; there is a suitable friction band on the training shaft which yields when one gun of the turret is fired, thus protecting the training gear from the distortion that would be caused by the severe lateral jump of the turret,—the line of recoil being outside the center of rotation. When not in use, the turret is secured by: (1) locking-bolts, which set up through the turntable to a bearing on the barbette; (2) outside turnbuckles, securing turret armor to the barbette armor; and (3) wedges, setting up between upper inside edge of barbette and lower outside edge of turret. (None of the training or of the securing gear is shown in the plates.) The main pressure-pipe (61) conveys the water from the pump to the water section (60) only part of which is stationary, the revolving part furnishing pressure to all the hydraulic machinery of the turret. The exhaust is conveyed from the turret to the feed-tank through (60) and (61) in a similar manner.

4. **The principal parts** of the mounting are:

Gun and Sleeve	Plate I.	Elevator	Plate IV.
Gun-Slide	" II.	Ammunition-Hoist,	" V.
Deck-Lugs	" III	Rammer	" VI.

5. **The sleeve** (formerly called "cradle") [Plate I (2)] is a large bronze casting to which the gun is secured by three front (6) and two rear (7) collars which fit in recesses machined in the gun-body; a key, fitting in grooves between gun and sleeve prevents the gun from turning. The sleeve rests on and is held to the slide-rails by clips (4) and (5). The piston-rod is secured to the lug (3) and recoils with the gun and sleeve.

6. **The recoil check** (Fig. 1) is of the hydraulic type, one cylinder being used both to check the recoil and to return the gun to battery. The cast-steel recoil cylinder (11), rifled with three tapered grooves, is bolted between the rails at the after part of the slide. It receives hydraulic pressure through (14) from a pipe leading from the water-collar [Plate III (29)] at the trun-

nions. A check-valve in the pipe at (14) closes and prevents the escape of water through it during recoil. The three relief-valves (16) are spring-weighted to 600 pounds and open downward to the overflow-chamber (21). The piston-rod (20) is of forged steel, partly bored out for lightness; it enters the cylinder through the stuffing-box (13) and bears the piston, which is shown in its "run-out" position.

7. When the gun is run out and in position to be fired, the piston-rod is drawn out of the recoil cylinder to its full length, and the latter would consequently be full of water, as the pump

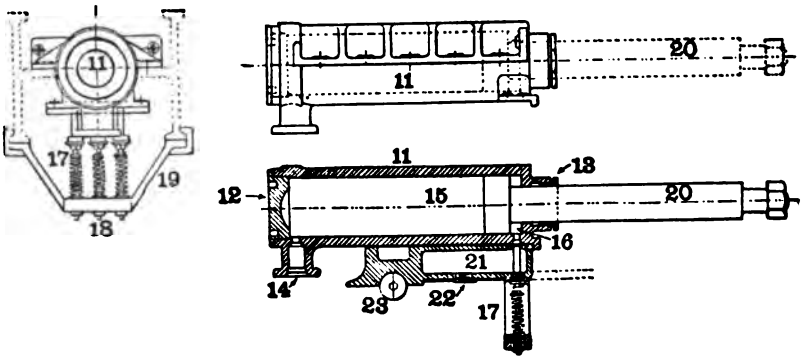
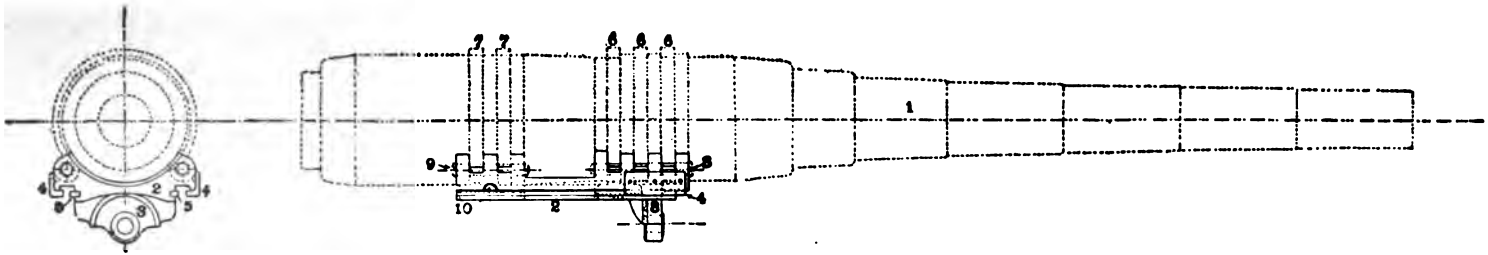


FIG. 1.

RECOIL-CHECK, 10-INCH TURRET MOUNT, MARK II. Art. 6.

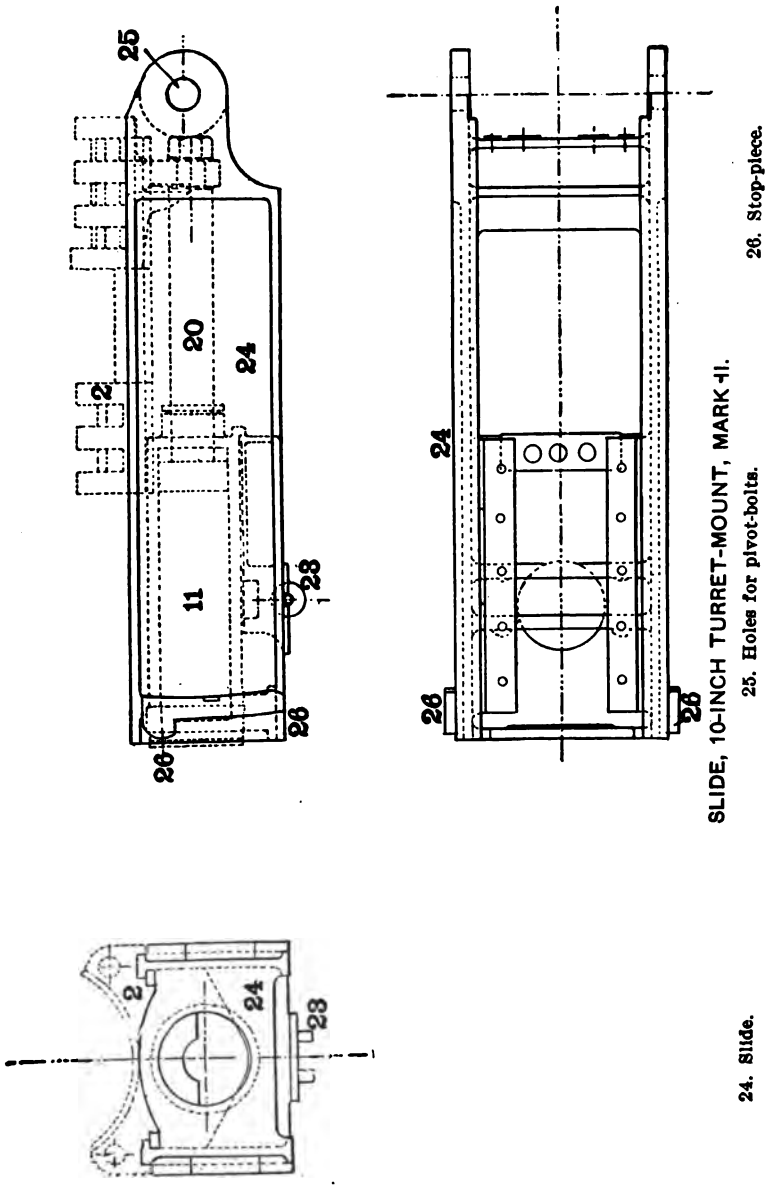
11. Recoil-cylinder.
12. Rear bonnet.
13. Stuffing-box and gland.
14. Opening for pump pressure and check-valve.
15. Pressure side.
16. Reverse side.
17. Relief-valve spring.
18. Relief-valve (center one).
19. Yoke.
20. Piston-rod, head and nut.
21. Overflow-chamber.
22. Connection for waste-pipe.
23. Lug for elevator connecting-rod.

must be in operation and the cylinder and hydraulic system filled, before the gun can be fired. The pumps are to be kept in operation during the firing. The walls of the recoil cylinder being cut with rifled grooves, the pump pressure is exerted on both sides of the piston, and the fluid would escape through the three spring valves (17) at the front end of the cylinder were the springs not set up sufficiently to resist the pump pressure, which is required to be maintained at 600 pounds per square inch.



SLEEVE AND GUN 10-INCH TURRET-MOUNT, MARK II.

1. 10-in. B. L. R.
2. Sleeve.
3. Recoil-lug.
4. Holding-down clips.
5. Holding-down gibs.
6. Front straps.
7. Rear straps.
8. Front-sleeve bolts.
9. Rear-sleeve bolts.
10. Hole for locking-bolt.



SLIDE, 10-INCH TURRET-MOUNT, MARK II.

25. Holes for pivot-bolts.

26. Stop-piece.

24. Slide.

8. Water is admitted to the recoil cylinder only at the rear end, through the aperture (14), and can escape only at the front end, as there is a check-valve in the supply-pipe (14), which closes when recoil takes place; otherwise the pipes or pump would be burst by the violent and sudden pressure due to recoil. When the gun is fired the piston-rod is driven into the recoil cylinder, and consequently must displace a quantity of water equal to the volume of the entering piston-rod. The fluid thus displaced escapes by the spring valves (17) into the overflow-chamber (21), and thence by a flexible hose attached to the opening (22) to the exhaust or waste-pipe, and back to the tank.

9. Recoil is taken up by the restriction of the fluid in passing from the pressure to the reverse side of the piston through the grooves in the cylinder, and, while the spring valves are on the reverse side, the tension on their springs does, in a manner, affect the recoil, and if they are set up too tightly, the length of recoil will be reduced. These springs should be set up so that the valves will be tight under the normal pressure of 600 pounds per square inch and no more. Care should be taken to see that the valves have a lift of not less than three-fourths inch, as this is necessary to give a proper valve-opening for the escape of the water when the gun is fired.

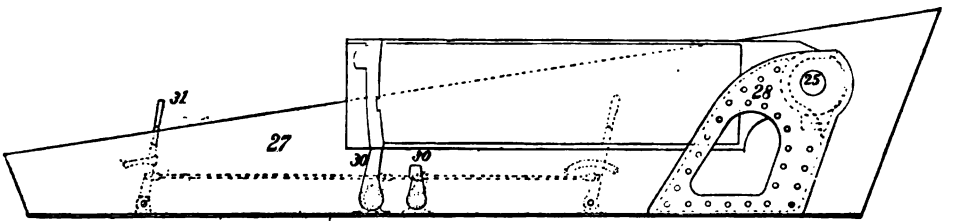
10. When recoil takes place, the check-valve in the pressure-pipe closes, but as soon as the gun is at rest the relief-valves close, pressure is admitted to the cylinder and its action on the rear face of the piston returns the gun to battery. The effective area for doing this work is the area of the piston-rod, since the same pressure acts on both sides of the piston.

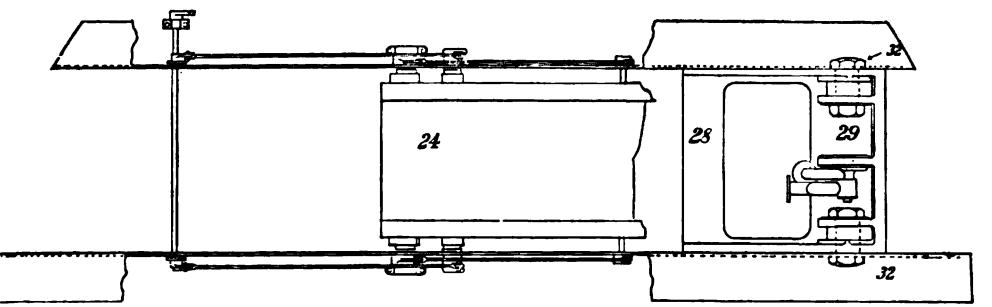
11. In securing the turret for sea, the guns are secured in the loading position, to 10 degrees elevation, and are run in on the slides the full distance. This is done by closing the valve in the pressure-pipe, opening the central relief-valve, which is specially fitted for the purpose, and then raising the muzzle a few degrees—whereupon the gun will run in by gravity; if it starts in too rapidly, its velocity may be checked by quickly lowering the muzzle. To run out again, see the springs of all relief-valves set up, and open the valve in the pressure-pipe, whereupon the gun will be forced out as in its counter-recoil.

12. The slide (Plates II and III) is a large steel casting with rails planed to fit the sleeve which, with the gun, is held to and rests upon them. It is trunnioned by the bolts (32) to the *deck-lugs* which are securely bolted to the turntable. The recoil cylinder is bolted to the after end of the slide and bears on its lower side the lug (23) to which the connecting-rod of the elevator is secured. The locking-lugs (30), or rest-lugs, are operated by the hand-lever (31), and bear upon the stop-piece (26). The gun has two locking positions; level, as shown, for use when ship is in port, and the loading position at 10° elevation; in the latter position the bearing surface near the top of (26) rests on the lug. The gun must be unlocked before firing.

13. The elevator (Plate IV) consists of a heavy cylinder (33) suspended from the turntable, beneath the rear end of the slide. The connecting-rod (35) is bolted at its upper end to lug (23) and its lower end rests in a ball-and-socket joint in the leather-packed ram (34); the elevator cylinder has a ring around its top (inside) which prevents the ram from being raised too high. A pipe connects the lower end of the elevator with the valve (36) which is operated by levers from the central sighting-hood. The pressure-pipe (39) and the exhaust-pipe (38) lead to this valve, by which either may be connected with the elevator cylinder. If pressure is turned on, the ram will raise the breech of the gun; if the cylinder is opened to exhaust, the gun, being mounted breech heavy, will be elevated.

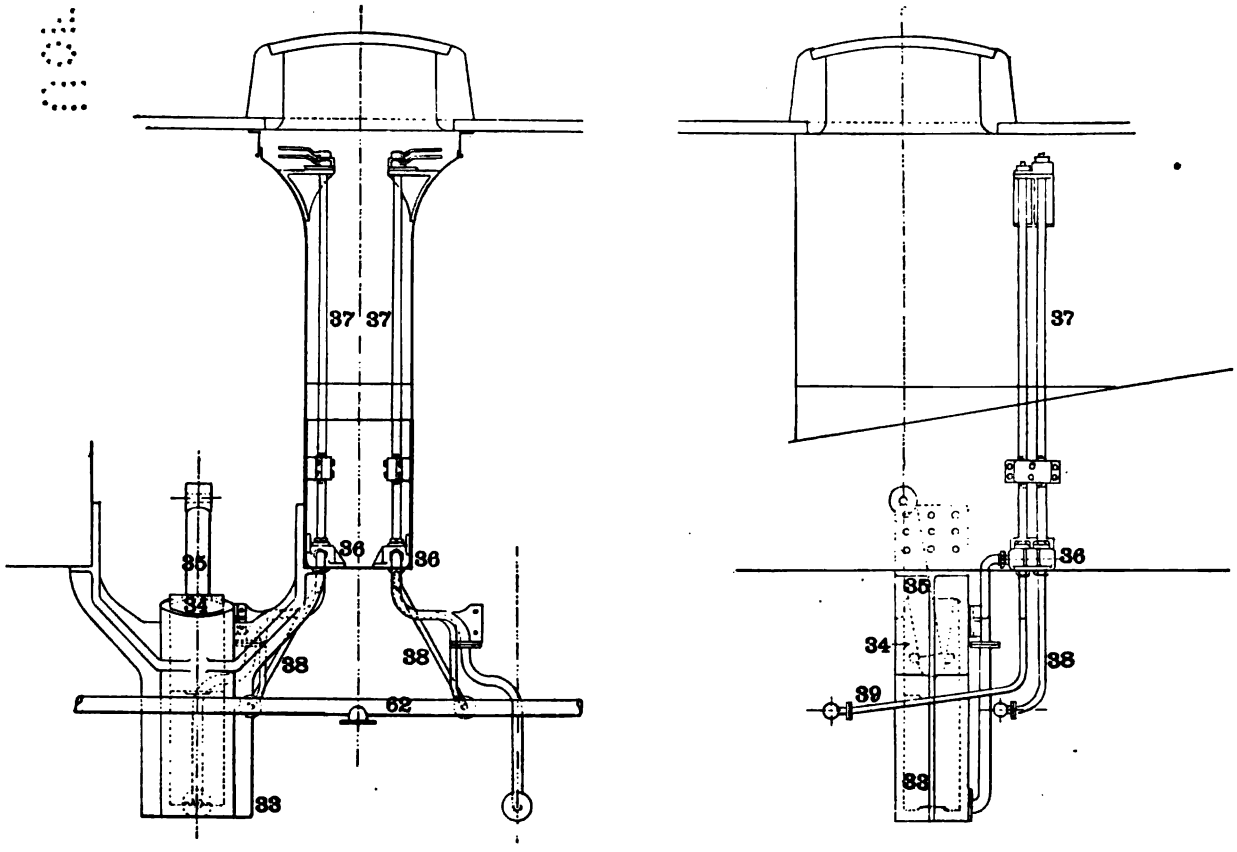
14. The ammunition-hoist (Plate V), of which there is one for each gun, is operated by the hydraulic motor (49) the controlling lever of which leads upward in rear of the gun. The motor is, in effect, a three-fold purchase worked backward, thereby gaining motion and losing power in the proportion of six to one. The outer end of the piston-rod and the closed end of the cylinder bear three sheaved blocks through which the wire fall of the hoist is rove. The standing part is secured to the motor and the other end reeves through the block (56), thence downward and is secured to the car (48); when the power is turned on the motor, the blocks are separated, the cable "overhauls" through the sheaves and the car is hoisted; the hoist of the car is to the extension of the motor piston-rod as six is to one. When for any reason there





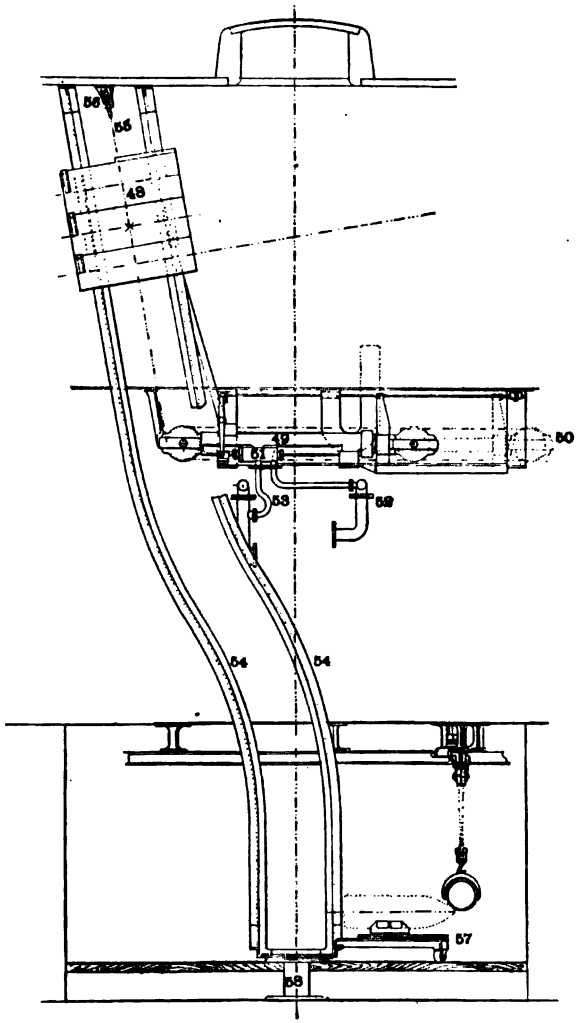
DECK-LUGS AND LOCKING-LUGS, 10-INCH TURRET-MOUNT, MARK II.

27. Turret-girders.
28. Deck-lugs.
29. Collar for pressure-pipe.
30. Locking-lugs.
31. Locking-levers.
32. Pivot-bolts.



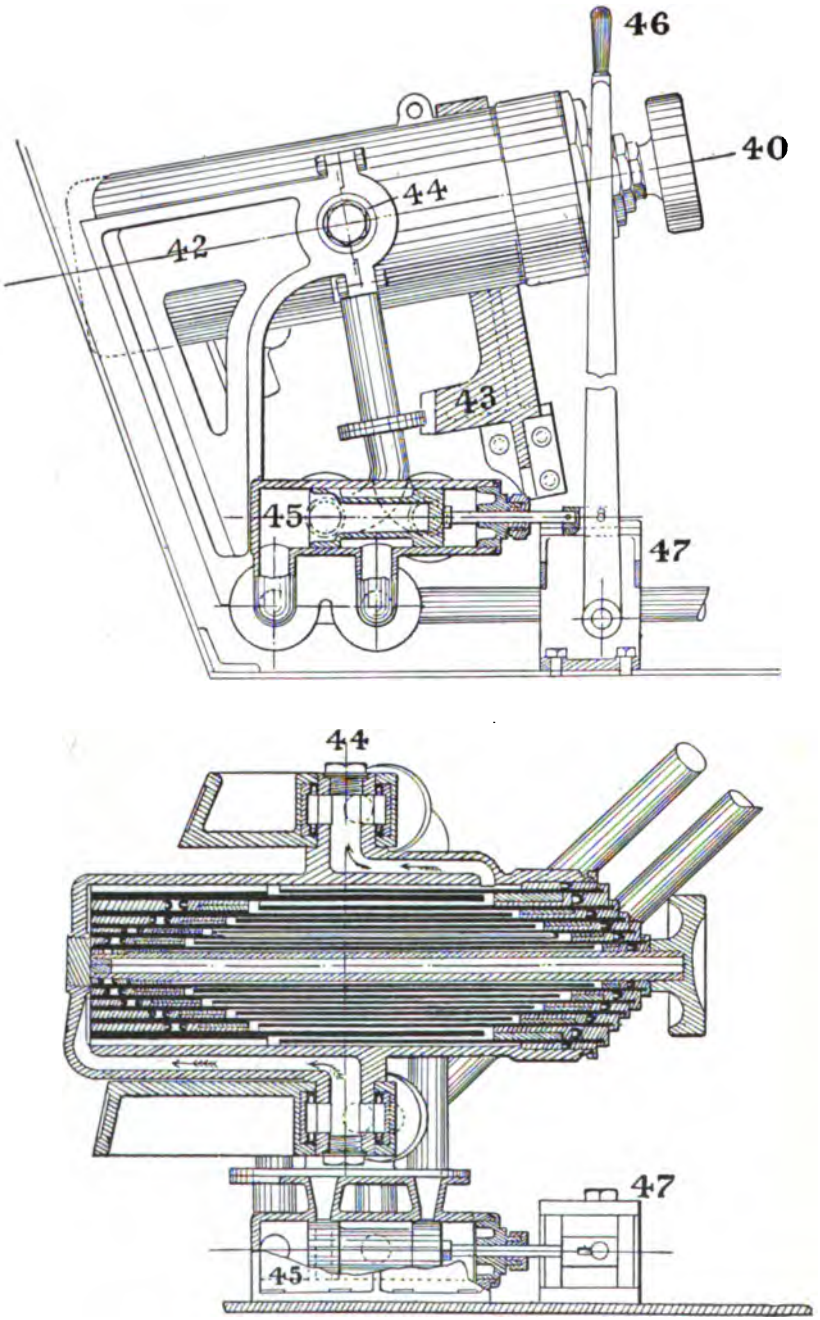
ELEVATOR, 10-INCH TURRET-MOUNT, MARK II.

33. Elevator.
34. " piston.
35. " connecting-rod.
36. Elevator-valves.
37. " valve-rods and levers.
38. Elevator pressure-pipe.
39. " exhaust-pipe.



AMMUNITION-HOIST, 10-INCH TURRET-MOUNT, MARK II.

48. Ammunition car.
49. " motor, run in.
50. " " run out.
51. " " valves.
52. " " pressure-pipe.
53. Ammunition-motor exhaust-pipe.
54. " " guide-rails.
55. " " wire fall.
56. Bracket and sheave.
57. Car and turntable for handling projectiles.



HYDRAULIC RAMMER, 10-INCH TURRET-MOUNT, MARK II.

is not power enough to hoist the car, the fall may be unrove from one sheave, making the above proportion five to one and gaining power accordingly. When the motor is opened to exhaust, the piston-rod is forced in and the car descends by its own weight. The guide-rails (54), on which the car travels, train with the turret and are curved to bring the car to the proper position for loading. The car (48) has three compartments, the two upper ones for powder, the lower one for the projectile; there are latches for preventing the contents from falling out when the car is inclined in hoisting. Stops, or hooks on the guide-rails, fix the position of the car in loading, and each compartment is in turn brought in front of the rammer. The car travels on the guide-rails by its rollers, and has pawls which will catch projections on the inside of the guide-rails in the event of any accident which would cause the car to fall.

15. The powder is brought from the magazine and placed in the car by hand; each gun having its own magazine and shell-room on the same level with, and opening into, the handling-room. Overhead trolley-rails lead from each shellroom to the ammunition hoist; the projectiles are handled by differential purchases, the upper blocks of which are hooked to cars travelling on the trolley-rails. From the purchases the projectiles are landed on the car (57) which is wheeled around a track, by hand or hydraulic power, until the projectile is pointed fairly into its compartment, when it is forced in by hand power.

16. The rammer (Plate VI) is secured to the turntable in rear of the gun in such a position that it delivers its stroke along the axis of the bore, when the gun is in its loading position. In the 10-inch turret-mounts, the rammer is, after loading, turned on its trunnions (44) into a vertical position to keep it clear of the recoil. The rammer, worked by hydraulic power, is telescopic; the sections are packed with U-shaped leather washers—one at the forward and two at the after end of each. The rammer-head is borne on the inmost section, which has the greatest travel. The controlling-valve (45), actuated by the hand-lever (46), is a piston valve with pressure space at each end and an exhaust space in

the middle; it operates as follows in extending and retracting the rammer. When the valve is moved forward, pressure is admitted through the right trunnion, while the contents of the rammer exhaust through the left trunnion, as shown by the arrows; this pressure, acting on the combined area of the rear ends of all the sections, extends the rammer with great force—each section starts as it feels the pressure, not being constrained by the others as to time of moving. To retract the rammer, the valve is moved rearward, opening the right trunnion to exhaust and the left one to pressure; each section has a collar around its rear end which affords the effective area for the pressure to act upon in retracting, since the pressure admitted through the left trunnion acts in both directions but upon different areas.

17. The high pressure of 600 pounds gives this type of rammer very severe shocks, similar in effect to water-hammering, particularly when the projectile suddenly stops on reaching its seat. Serious breakdowns have been the result, and in some turrets, hydro-pneumatic rammers, working on the same principle but having the advantage of air cushioning, have been substituted.

18. Miscellaneous fittings.—The turret is covered with three-inch armor-plates, built into which are the sighting-hoods with platforms directly below,—on which the trainer and the gun-pointer stand. The training-hood, situated forward, outside the left gun, contains the trainer's sight and a control-lever for the turning-engine. The gun-pointer's hood is between the guns, near the center of the turret. This station contains a control-lever for the turning-engine and a clutch for connecting and disconnecting it and the lever in the training-hood, both of which cannot be in operation at the same time; a speaking-tube to the training-hood; a telescopic sight and a firing-key for each gun; and the control-levers for the elevators.

19. An electric fan is placed behind each gun to drive the smoke out of the turret. A hinged grating, on which the loader stands when performing his duties, covers the opening up which the ammunition-car passes; it must be hinged up before the car is raised. There are suitable ladders for gaining access to the handling-room; an opening on each side of the turret roof is protected

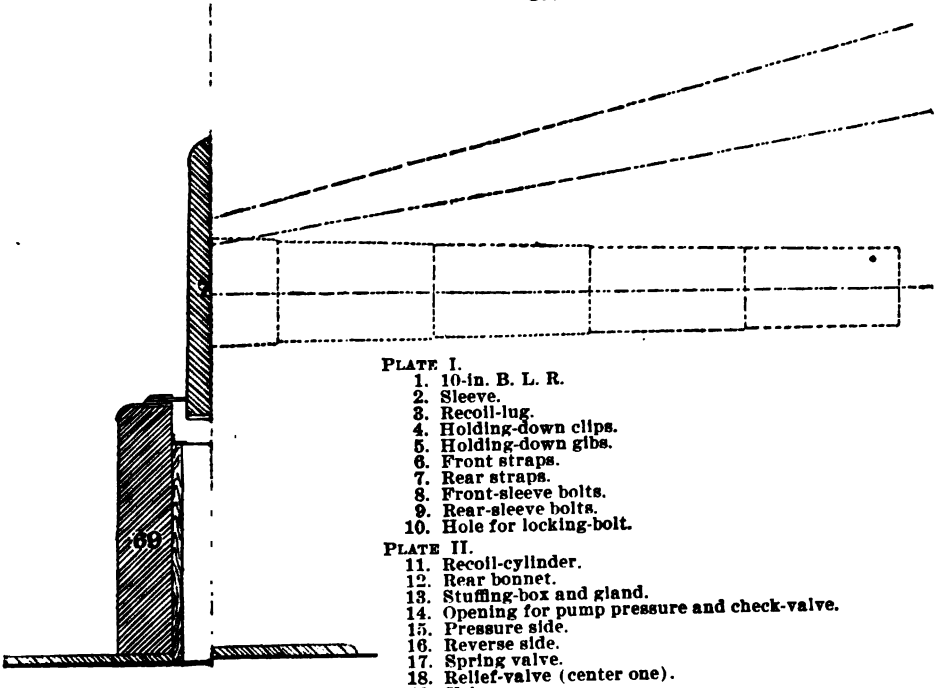


PLATE I.
1. 10-in. B. L. R.
2. Sleeve.
3. Recoil-lug.
4. Holding-down clips.
5. Holding-down gibs.
6. Front straps.
7. Rear straps.
8. Front-sleeve bolts.
9. Rear-sleeve bolts.
10. Hole for locking-bolt.

PLATE II.
11. Recoil-cylinder.
12. Rear bonnet.
13. Stuffing-box and gland.
14. Opening for pump pressure and check-valve.
15. Pressure side.
16. Reverse side.
17. Spring valve.
18. Relief-valve (center one).
19. Yoke.
20. Piston rod, head and nut.
21. Overflow-chamber.
22. Connection for waste-pipe.
23. Lug for elevator connecting-rod.
24. Slide.
25. Holes for pivot-bolts.
26. Stop-piece.

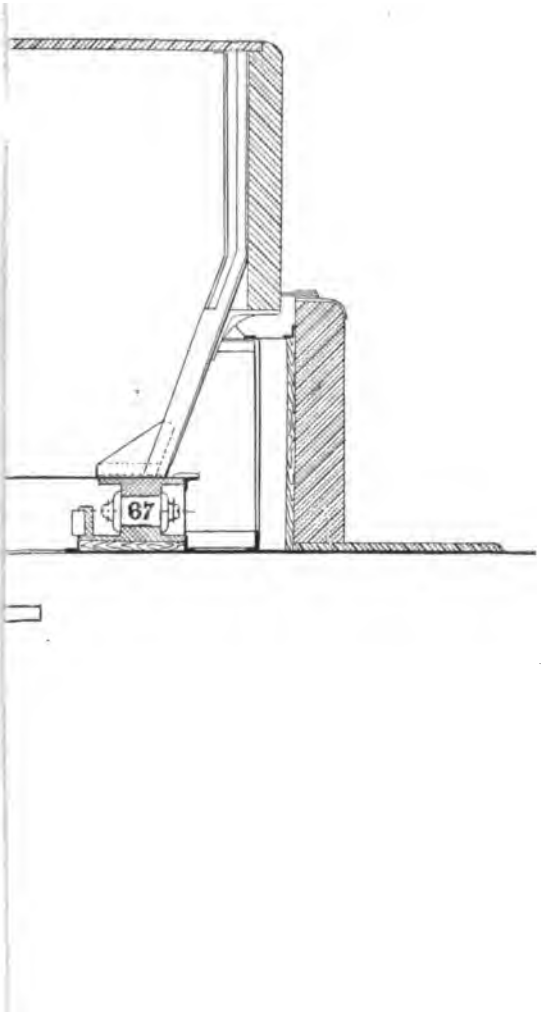
PLATE III.
27. Turret-girders.
28. Deck-lugs (carriage).
29. Collar for pressure-pipe.
30. Locking-lugs.
31. Locking-levers.
32. Pivot-bolts.

PLATE IV.
33. Elevator.
34. " piston.
35. " connecting-rod.
36. " valves.
37. " valve rods and levers.
38. " pressure-pipe.
39. " exhaust-pipe.

PLATE VI.
40. Hydraulic rammer in loading position.
41. " " in firing position.
42. " " brackets.
43. " " transom.
44. " " trunnions.
45. " " valves.
46. " " operating lever.
47. " " fulcrum for lever, and guide for [valve-stem.

PLATE V.
48. Ammunition-car.
49. " " motor run in.
50. " " " run out.
51. " " " valves.
52. " " " pressure-pipe.
53. " " " exhaust-pipe.
54. " " guide-rails.
55. " " wire rope fall.
56. " " bracket and sheave.
57. Car and turntable for handling projectiles.

PLATE VIII.
58. Pedestal for central column.
59. Central column.
60. Water section.
61. Pressure-pipe.
62. Exhaust-pipe.
63. Platform.
64. Ladder to turret.
65. Sights.
67. Rollers.
68. Roller Paths.
69. Barbette.
70. Turret.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by armor gratings; hand gear is fitted only to the turning gear. Valves are placed in each exhaust and pressure-pipe in the turret as well as in the main exhaust and pressure-pipes.

20. The 12-inch turret-mounts of the U. S. S. Texas have a closed recoil cylinder and two auxiliary running-out motors for each gun; the auxiliary or gun-working motors have no part in checking the recoil.

CHAPTER XVI.

12-INCH TURRET-MOUNT, MARK IV.

1. The Mark IV turret-mount, on which are installed the 12-inch guns of the battleships Maine, Missouri, and Ohio, and the monitors Arkansas, Wyoming, Nevada, and Florida, is a *hydraulic-recoil spring-return mount* in which all machinery is electrically operated and controlled.

2. The 13-inch turret-mounts of the Kearsarge, Kentucky, Illinois, Wisconsin, and Alabama are very similar, the later turrets being improvements on the earlier designs.

3. Plate I is a vertical longitudinal section between the guns showing the left mounting in profile. Plate II is a plan of the left half of the turret (section taken at the level of the trunnions). Plate III is a cross-section of the left half of the turret showing the recoil cylinders and gun-slide in profile and in section. The following description is written for the Arkansas and, except as to the training-gear, corresponds closely to the turrets of the other ships mentioned. The main difference among these turrets lies in the training-motors and their connections,—both mechanical and electrical. The motors of the Wyoming and Ohio are both of 20 H. P. and are secured to the *turntable;* those of the remainder of the Arkansas and Maine classes are of 35 H. P., and for all the 13-inch turrets of 50 H. P., all of which are secured to a *stationary part* of the ship and work upon the turntable.

4. For operating the motors of the mounting, exclusive of the training-motors, one 32-kilowatt dynamo is required or the power may be taken from the switchboard. The two 20 H. P. ammunition-hoist motors are shunt-wound while the 5 H. P. rammer-motors and the elevating-motors, of about the same power, are series-wound; all are controlled by ordinary electric-car controllers. In lieu of main fuses, mechanical circuit-breakers are placed in all but the rammer circuits; the motors, when start-

ing, have to overcome the inertia of the heavy moving parts, thus throwing large currents through the armatures which would frequently blow out fuses—particularly if handled by inexperienced men. Since the circuit-breakers can be quickly thrown "in" again, much time that would otherwise be wasted in replacing fuses is saved; if the controller-levers are put over one division at a time when starting, the circuit-breakers will not act, as long as everything is in good order; but if the levers be thrown around quickly, the heavy current will nearly always break the circuit before the armature can start.

5. Training-motors.—The two training-motors act on diametrically opposite portions of the training-rack, their armatures being in parallel and their shafts cross-connected mechanically. Motors employed in pointing turret-guns need great torque in starting and counter-torque in stopping, because of the inertia and momentum of the moving parts; in the Arkansas, the weight is 370 tons and its radius of gyration about 11 feet. To obtain the necessary torque, and the quick and accurate starting and stopping essential for placing and holding the sights on the target, an especially designed system of electrical control is employed.

6. In the Ward-Leonard system, which is generally used, the current for the motors is supplied by a dynamo that, while being used for this purpose, cannot furnish current for any other purpose. Its series-field is shunted by a low-resistance switch on the headboard so that only part of the armature current flows through it; this current varies in strength. The shunt-field is entirely disconnected from the armature current and is excited from the power bus-bars of the switchboard, the exciting current being regulated by the trainer's controller in the turret. The training-motors are also separately excited from the power bus-bars but their field strength is constant and is controlled by a field-switch in the turret. Thus the speed of the motors is controlled by varying the resistance in the shunt-field of the dynamo; its speed of rotation being constant, its E. M. F. varies at the terminals. Since the motor-armatures rotate in a magnetic field of constant strength, their speed is directly proportional to the E. M. F. at

CHAPTER XVI.

12-INCH TURRET-MOUNT, MARK IV.

¶ The **Mark IV turret-mount**, on which are installed the 12 [illegible] Maine, Missouri, and Ohio, and the [illegible], Wyoming, Nevada, and Florida, is a *hydraulic spring return mount* in which all machinery is electrically operated and controlled.

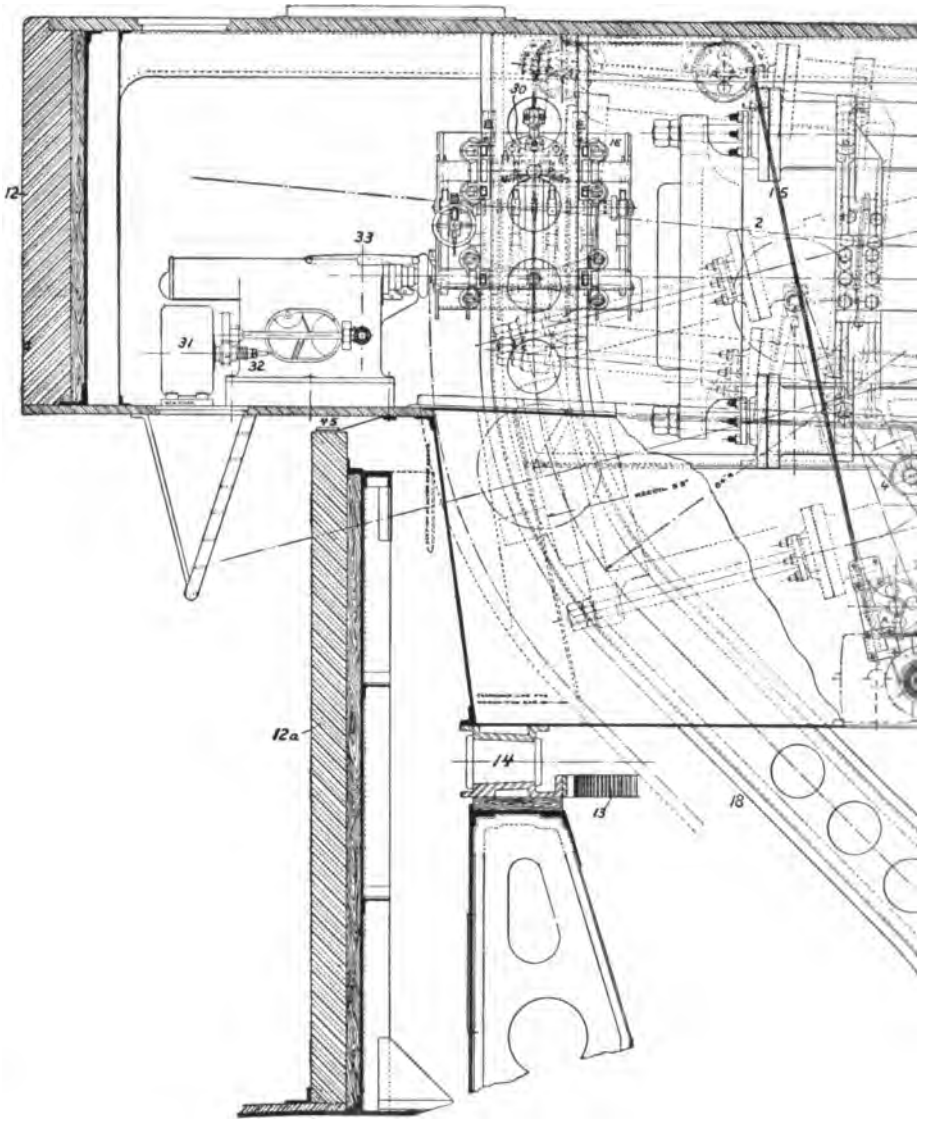
¶ The **12-inch turret-mounts** of the Kearsarge, Kentucky, [illegible], and Alabama are very similar, the later turrets having improvements on the earlier designs.

¶ Plate I is a vertical longitudinal section between the guns of the left mounting in profile. Plate II is a plan of the left half of the turret (section taken at the level of the trunnions). Plate III is a cross section of the left half of the turret showing the recoil cylinders and gun-slide in profile and in section. The following description is written for the Arkansas and, except where otherwise noted, corresponds closely to the turrets of the other mountings mentioned. The main difference among these turrets lies in the training motors and their connections,—both mechanical and electrical. The motors of the Wyoming and Ohio are both 40 H. P. and are secured to the *turntable;* those of the remaining ships of the Arkansas and Maine classes are of 35 H. P., and for all the 12-inch turrets of 50 H. P., all of which are secured to a *stationary part* of the ship and work upon the turntable.

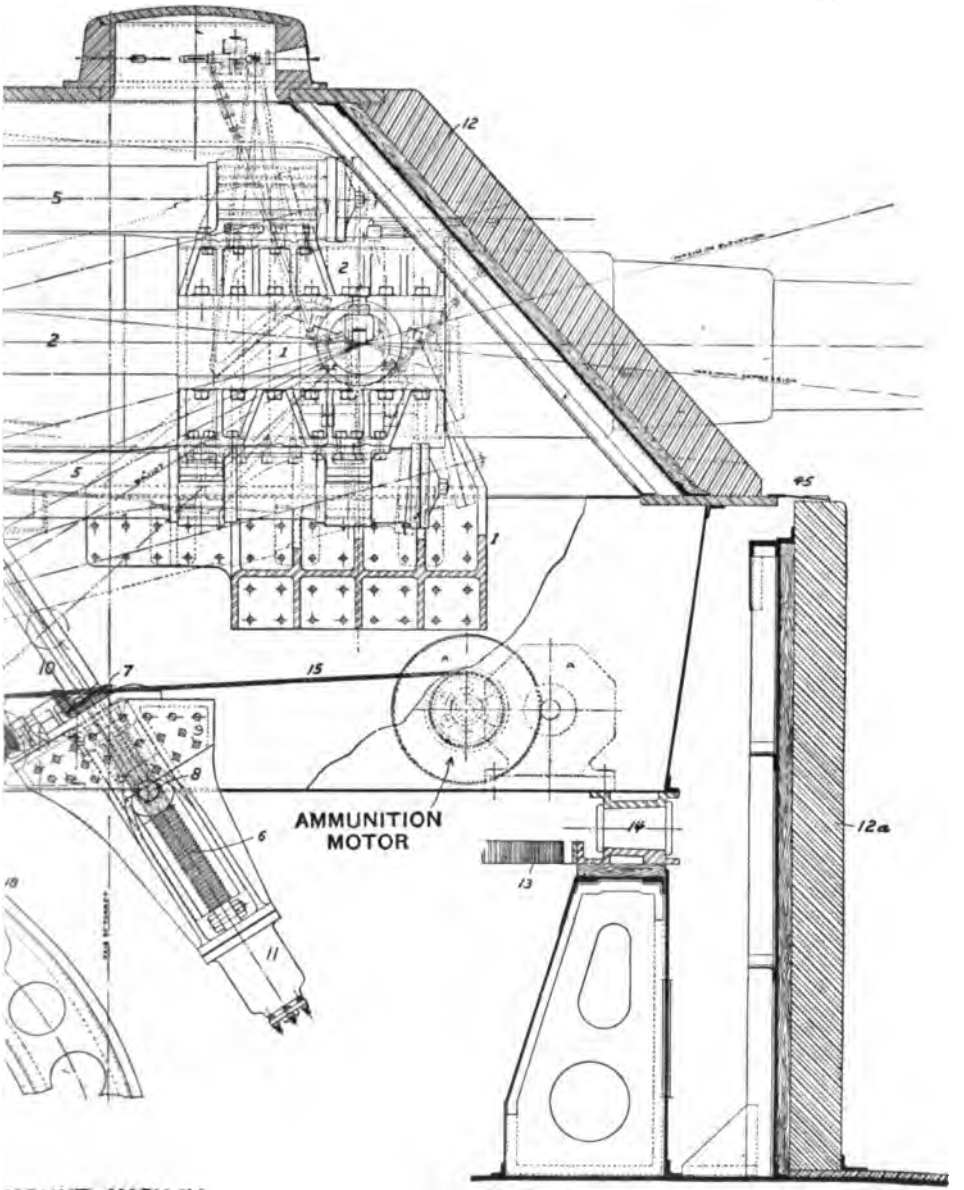
¶ For **operating the motors of the mounting,** exclusive of the training motors, one 32-kilowatt dynamo is required or power may be taken from the switchboard. The two 20 H. P. ammunition hoist motors are shunt-wound while the 5 H. P. rammer motors and the elevating-motors, of about the same power, are series wound; all are controlled by ordinary electric controllers. In lieu of main fuses, mechanical circuit-breakers are placed in all but the rammer circuits; the motors, when

ing have to overcome the inertia of the heavy [illegible] throwing large currents through the armature [illegible] frequently blow out fuses—particularly if handled [illegible] Since the circuit-breakers can be [illegible] time that would otherwise be [illegible] saved. If the controller levers are [illegible] time when starting, the circuit breaker [illegible] starting is in good order; but [illegible] the heavy current [illegible] before the armature can start.

5. Training-motors.—[illegible] opposite hand [illegible] ring in parallel and [illegible]



12-INCH TURRET



MOUNT, MARK IV.

the terminals; they are reversed in the ordinary manner by the controller, which, in its "off" position, short-circuits the armatures.

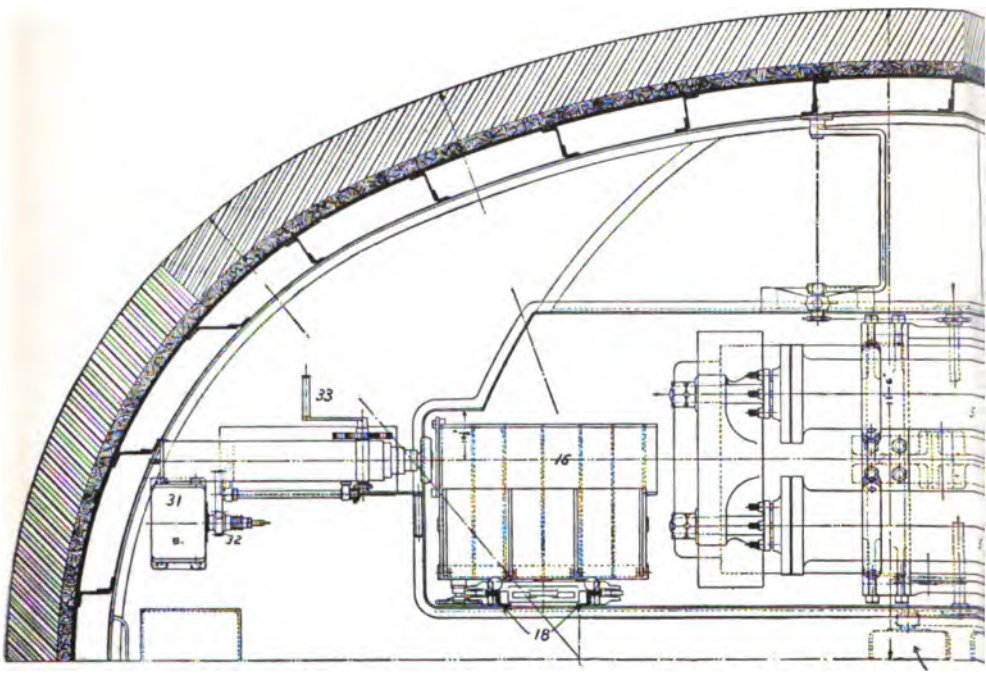
7. An improvement of this system has passed a successful trial on the Nevada and will be adopted. The change is to introduce a motor-generator between the training-motors and the dynamo and thus permit the latter to supply other power circuits even while training the turret. The motor-generator is installed in the turret, on one shaft, and runs at a constant speed. The field of its motor is separately excited and is controlled from the turret so that it corresponds to the dynamo in the first plan, as outlined above.

8. **The "series-parallel"** system, installed in the Ohio and the Wyoming, also takes current at constant voltage from the main switchboard. The motors are compound-wound, with their shunt-coils adjusted to receive a constant current of about 4½ amperes. The motor-armatures have a primary and a secondary winding in the proportion of four to one, each winding having its own commutator. While starting the turret, both windings are thrown in series by putting the controller on the first notch, which gives a powerful torque; after the first notch, the primary winding is cut out. Working off the shafting of each motor, is a small hydraulic cylinder; the ends are joined by a by-pass pipe, in which is a relief-valve, as well as by a pipe in which there is a plug-cock that is mechanically connected to the electrical controller. As the motors revolve, they work the pistons of the hydraulic cylinders back and forth and force the liquid from one end to the other through the plug-cocks; these latter regulate the amount of liquid that can pass by the size of their opening. This opening is designed to be proportional to the speed of the turret on the several notches of the controller so as to offer practically no resistance, by the flow of the liquid, to steady turning, but to prevent sudden and irregular movements of the turret. In the "off" position of the controller, the plug-cocks are closed and the turret cannot turn, except by forcing the liquid through the relief-valves; this happens when the turret is suddenly stopped. There is no mechanical connection between the motors of these turrets, except

that the plug-cocks of the two cylinders are both connected to the one controller-shaft.

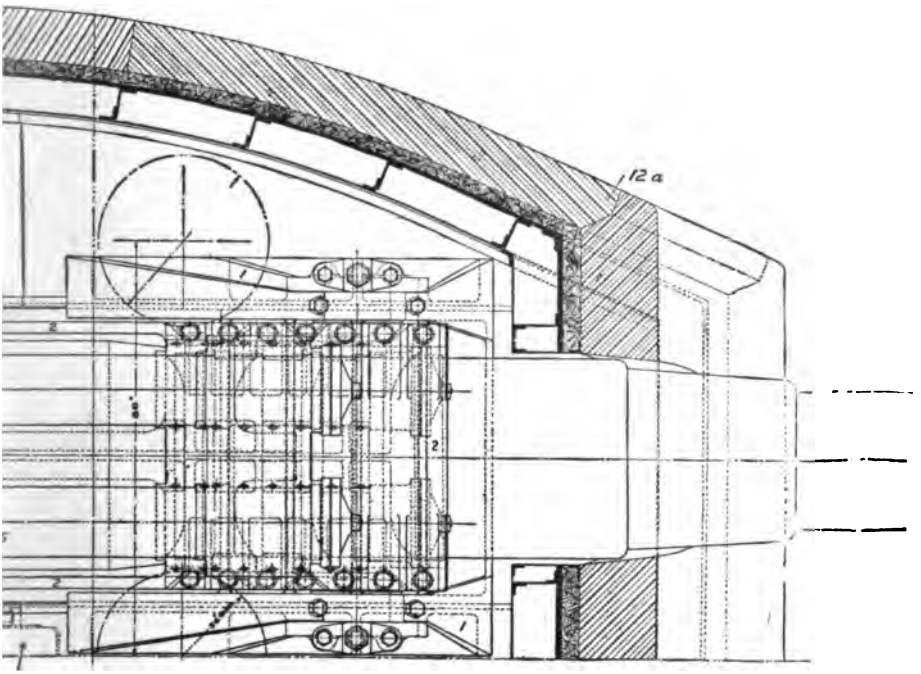
9. The turntable, to which the turret armor and all revolving parts of the mounting are secured, is built up of steel plates and angle-irons and rotates on live rollers (14), which travel on a roller-path built up inside the barbette framing. The cone-shaped rollers are spaced by two floating-rings which are secured to their axles; the weight of the revolving parts of the installation rests upon the rollers and the horizontal thrust of the guns in recoiling is transmitted to the ship by their flanges. The circular barbette (12a), 8 inches to 12 inches in thickness, extends from the armored deck well above the turntable, while the guns and upper parts of their mountings are protected by the turret (12), 11 inches to 12 inches in thickness, which rests upon the turntable and joins with the barbette armor. The turntable is revolved by two 35 H. P. training-motors which are placed beneath the armored deck outside the barbette structure and operate vertical training-shafts placed diametrically opposite each other, with respect to the axis of rotation of the turntable. These shafts are stationary and bear, on their upper ends, pinions which gear in the circular training-rack (13) of the turntable. There is a friction-collar on each shaft which yields to the twist given the turret on firing one of the guns and prevents the training-gear from being deranged by it. The training-shafts are cross-connected by shafting and bevel gearing, which insures that the two motors shall turn at the same rate, and enables one motor to turn both shafts, should it become necessary. Suitable hand-gear, which may be thrown in by a clutch (at the same time disconnecting the motor), is installed at each motor.

10. The turret is secured for sea by: (1) the *locking-bolt,* operated inside the turret, the principal use of which is to fix the securing position of the turret; it passes through the turntable to a socket near the top of the barbette and will go in place only when the turret is accurately placed in the securing position; (2) *wedges,* setting up between the upper inside edge of barbette armor and the lower outside edge of turret armor; these wedges, four in number, prevent any severe strain on the roller-flanges,



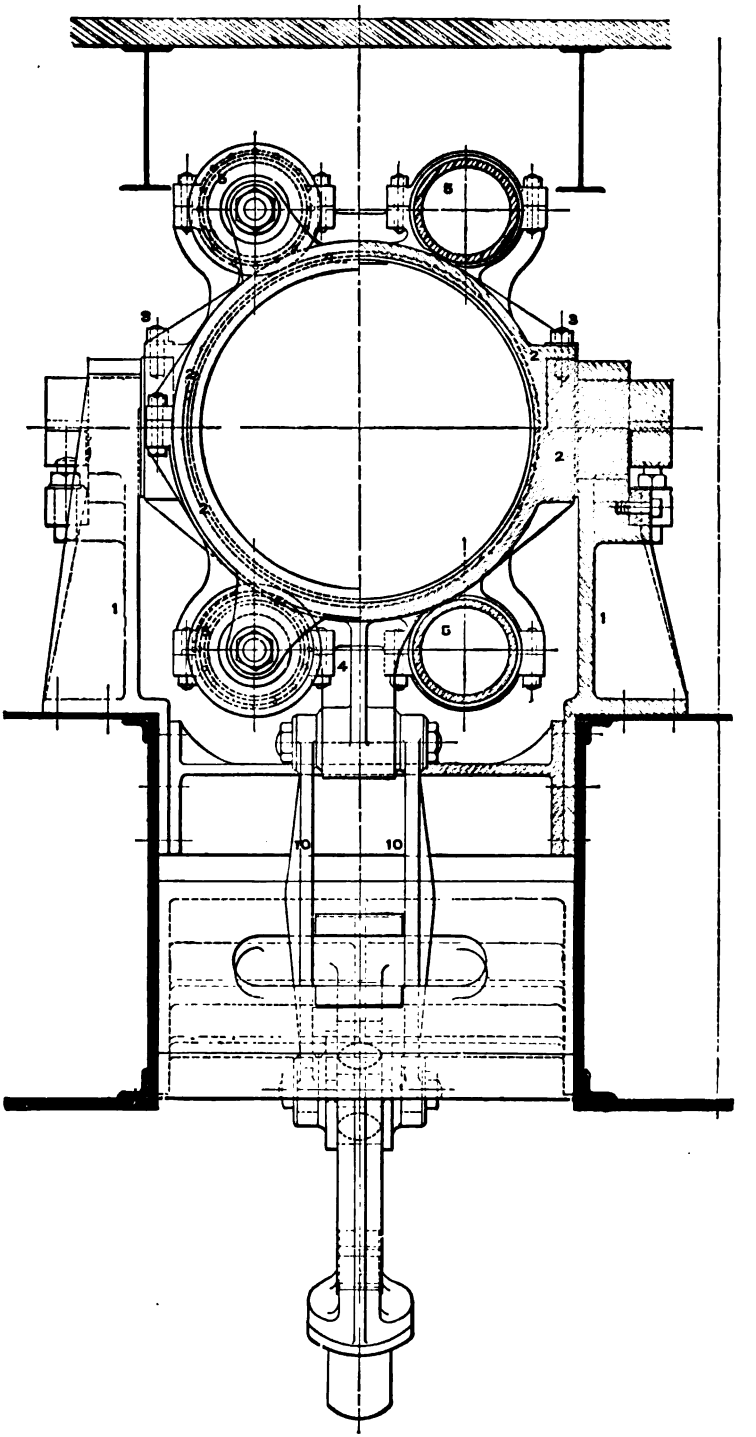
ELEVATING

12-INCH TURRET-M0

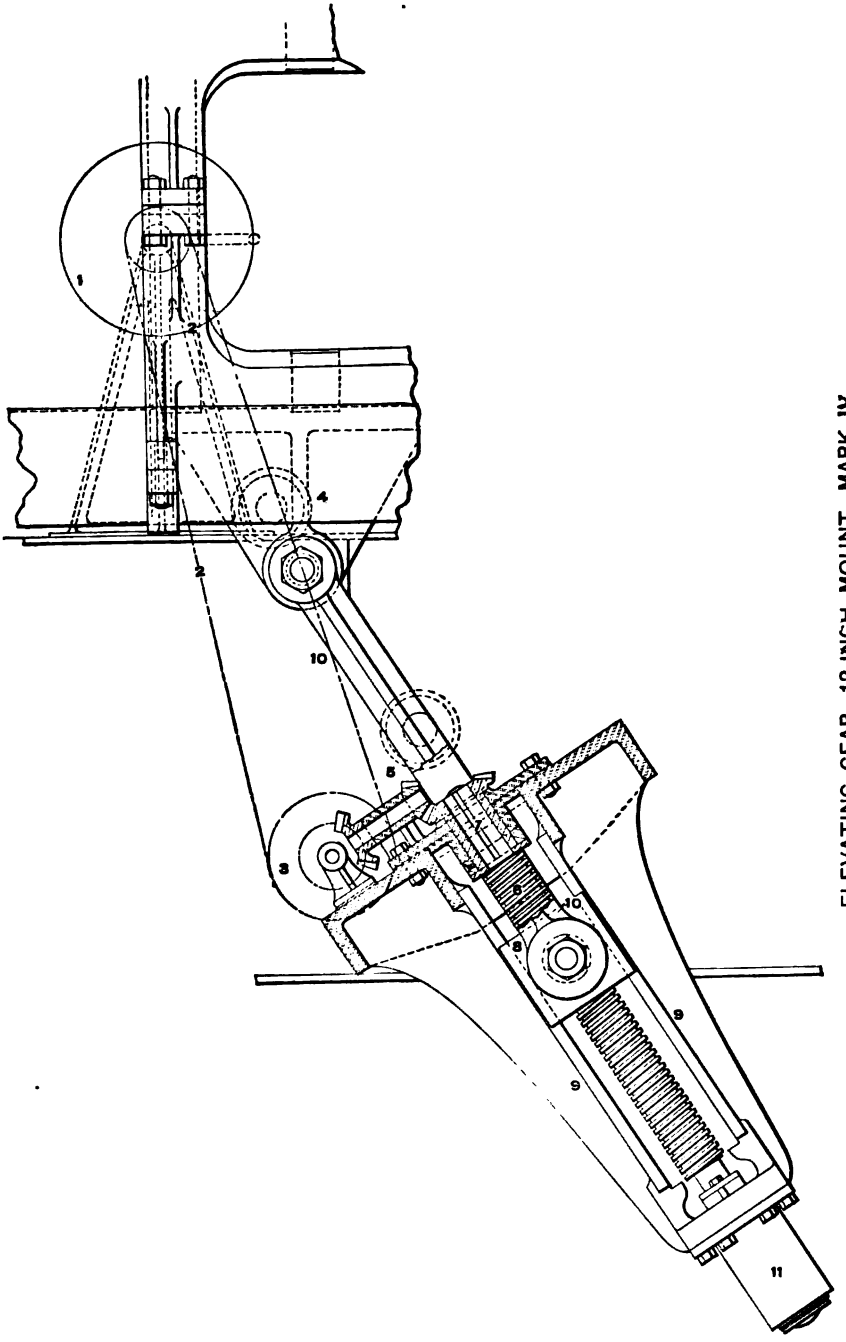


)TORS

UNT, MARK IV.



12-INCH TURRET-MOUNT, MARK IV.



ELEVATING GEAR, 12-INCH MOUNT, MARK IV.

as the ship is listed; (3) outside *turn-buckles,* which secure the turret to the barbette armor. (None of the securing gear is shown on the plates.) The apron (45) rotates with the turret and, when lowered, bears on a gasket on the barbette and makes a watertight joint; it must be raised before turning the turret. The principal parts of the mounting are:

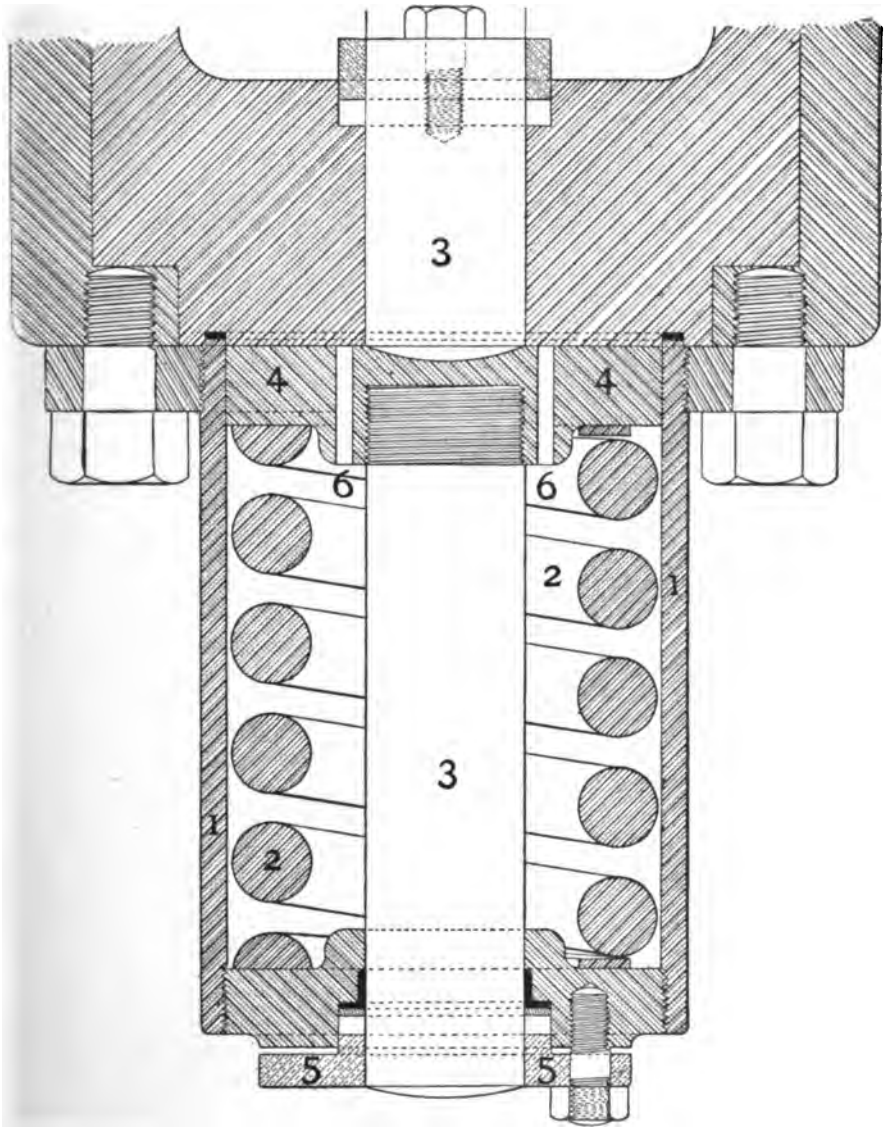
(1) The gun and gun-slide.
(2) The recoil-cylinders.
(3) The deck-lugs.
(4) The elevating-gear.
(5) The ammunition-hoist.
(6) The rammer.

11. The gun-slide [Plates I, II, and III (2)], in which the gun rests, is a sleeve built up of several steel castings bolted together; it is bushed with bronze, giving the gun a bearing at the trunnions five feet in length and a shorter one near the breech; the trunnions are parts of the slide and are placed at the center of gravity of gun and slide combined; knife-edged trunnions are shown but are not fitted in all 12-inch mounts of this type. The four cast-steel recoil-cylinders are secured to the slide by collars bolted over each end. The connecting-rods (10) of the elevating-gear, are bolted to the lug (4) which is cast on the slide.

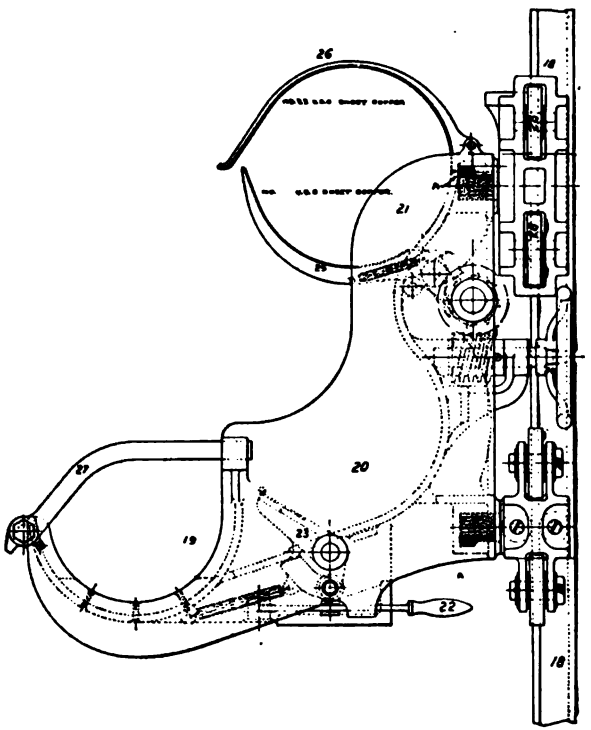
12. The recoil-cylinders [Plates I, II, and III (5)], four in number, are secured to the slide while their piston-rods, projecting through stuffing-boxes at the rear ends, are secured to a yoke around the breech of the gun: because of the inclined turret-front the upper cylinders are made two feet shorter than the lower ones. The two upper and the two lower cylinders are connected by equalizing pipes and all are rifled with tapering grooves in the usual manner. The counter-recoil springs surround the piston-rods and are divided, by separating disks, into seven and nine sections respectively in each of the upper and lower cylinders; the springs are made in three sizes and in three diameters, the outside spring being made of the largest wire. The recoil with full charge of powder is about 33 inches.

13. The *deck-lugs* (1), which bear the trunnion-seats and cap-squares, are heavy steel castings bolted to the turntable.

14. The elevating-gear (Plates I, III, and IV) is actuated by a 3½ H. P. motor, placed between the guns under the turret floor, whose armature-shaft gears with the shaft (2). The motor



HYDRAULIC ELEVATOR-BUFFER, 12-INCH MOUNT, MARK IV.



AMMUNITION-CAR, 12-INCH TURRET-MOUNT, MARK IV.

is thus directly connected by shafting to the bevel-wheel (7), held by a feather to the elevator-shaft (6) in such a manner that the elevator may have a slight downward motion through, but must turn with, (7); this mechanism is carried on a heavy bracket (9) bolted to the turntable. By turning the elevating motor in either direction, the elevator-shaft is revolved and, it being practically restrained from a motion of translation, the travelling-nut (8), to which the lower ends of the connecting-rods (10) are secured, is moved along its guides and the breech is raised or lowered. In Plate IV (1) is the hand elevating-wheel, connected by the chain (2) and the sprocket-wheel (3) to the shaft to which the motor is geared; it is not necessary to disconnect the motor when using the hand-gear.

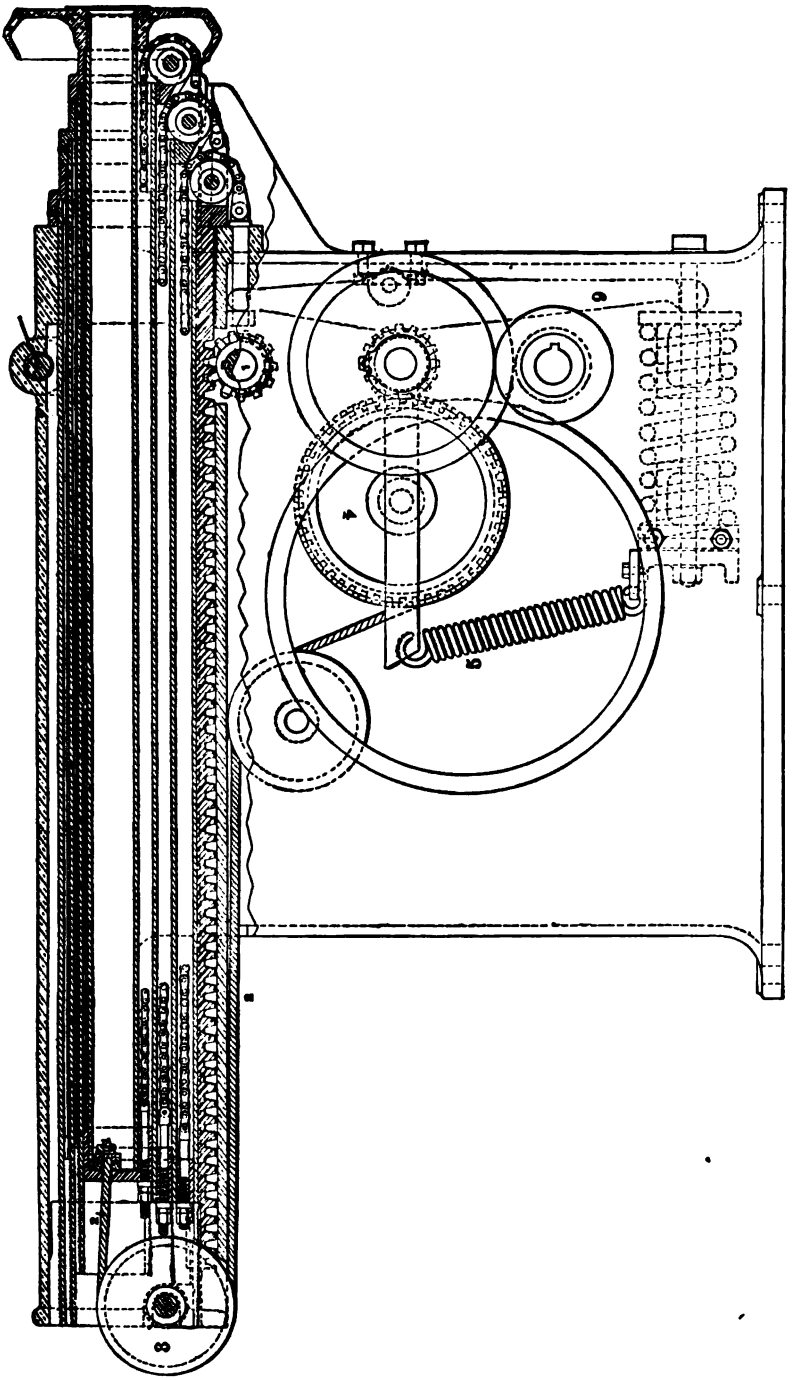
15. The dash-pot (11) is bolted to the elevator-bracket and contains the mechanism for controlling the *jump;* it is shown in detail by Plate V. The lower end of the elevator-shaft rests on the dash-pot piston (4); the spring (2), under considerable initial tension, keeps the shaft pressed upward against a collar at its upper end and, in the ordinary working of the gun, does not yield but holds the shaft up in place. When the gun is fired, however, the elevator-shaft is driven down forcibly, by the jump, and the piston (4) is pressed downward against the spring; when the jump has been thus absorbed, the spring brings the gun back to its former position. The dash-pot is filled with recoil-liquid which, escaping through the holes (6), cushions the movement of the piston in each direction. In the place of the dash-pot, a simpler device is fitted to many mounts. The elevator-shaft rests on a heavy saucer-shaped piece of brass which is supported by the elevator-bracket; sufficient elasticity is obtained in this way.

16. The ammunition-hoist—one for each gun—is worked by a 20 H. P. motor secured to the turntable, beneath the turret floor, directly below the gun-port; the motor is controlled from the turret in rear of the gun. The armature-shaft is geared to a drum on which is wound a three-inch wire cable (15) which passes over leading-blocks at the top of the turret and is secured to the ammunition-car (16). The car travels on the guide-rails (18)—

leading upward from the handling-room—which are a part of and rotate with the turntable. Each gun has its own magazine and shellroom, opening into a common handling-room, and the turret and handling-rooms are, with their crews, under the charge of the turret-officer. The projectiles are lifted by differential purchases, rolled to the handling-room on overhead trolleys and landed on the handling-room car from which they are pushed by hand into the ammunition-car. The powder-charge is made up in four sections and is transferred from magazine to car by hand.

17. The ammunition-car (Plate VI) travels by its rollers (28) on the guide-rails (18) and has but two positions of rest, the loading-position, opposite the rammer, and the charging-position in the handling-room; but the car will remain in any position on the rails when the power is cut off the motor,—an electrically actuated brake holding the motor's armature-shaft rigidly, whenever power is *off* the motor. The upward motion is limited by stops and the loading-position just below is fixed by the loading-hook (not shown). The projectile is brought up in the lowest compartment (19) which is the only one that comes opposite the rammer-head; the shell-latch (27) keeps the projectile in place while it is being hoisted. The first powder-section rests in (20) on the powder-tray (23); the hand-lever (22) trips this tray, whereupon the powder rolls down opposite the rammer. The last section of powder is brought up in (21), the powder-tray (25) being tripped by the powder-wheel (24). The hinged copper cover (26) protects the powder from injury while it is in the car. The hoisting-cable is secured to the upper ends of two pawls [(30) Plate I] which are held clear of their rests by the weight of the car as long as everything is in good order; if the cable should carry away, however, these pawls will be forced by springs into their rests on the guide-rails and the car will not fall.

18. The rammer (Plates I, II, and VII) is a telescopic chain-rammer actuated by a 5 H. P. electric motor; the rammer is secured to the turret floor in a position such that it will deliver its stroke along the axis of the bore when the gun is in its level or loading-position. The motor (31), which is connected by geared shafting to the pinion (1) (Plate VII), actuates the motor



TELESCOPE RAMMER, 12-INCH MOUNT, MARK IV.

in extension and in retraction; the friction-disk (32) is designed to yield when the rammer is brought up suddenly (as when the projectile stops on reaching its seat), and to thus prevent the mechanism from being strained by the momentum of the armature. The rammer may also be worked by the crank (33) which, when connected, gears with the pinion (1).

19. The rammer consists of five sections of hard-drawn brass tubing, fitting one within the other, the outer section being stationary, mounted on suitable framing about 2½ feet above the turret floor; the rear end of each section, except the outer one, is connected by a chain passing over a roller at the front end of the next larger section to the front end of the second outside section; for instance, the inner section is connected to the third. On the lower side of the outside section is a rack, extending nearly its whole length, and a pinion (1) gearing into it; the section can be made to move forward by the motion given to the pinion by either hand- or electric-power applied, by suitable gearing, to the shaft on which the pinion is mounted. The forward motion of the outer section opens out each of the other sections by the same amount and when the outer section has travelled forward the length of the rack, the rammer-head on the innermost section has reached the limit of its travel. A ⅜-inch wire rope is secured to the inner section, passes over the leader (3) and around the drum (4) to which it is secured. The drum is so connected to (1) that the cable will be paid out at the proper rate while the rammer is being extended; and, when the motor is reversed, the drum winds in the cable, drawing back all the sections but the outer one, which is withdrawn by the pinion (1) which extends it. The spring (5) relieves the shock when the sections are drawn back too forcibly; the spring buffer (6) assists the friction-disk in cushioning shocks in the extension of the rammer.

20. In the future, rammers are to be built on the above principle, but the chains will be on top of the sections, thus helping support the weight when the rammer is extended and preventing the sections from binding.

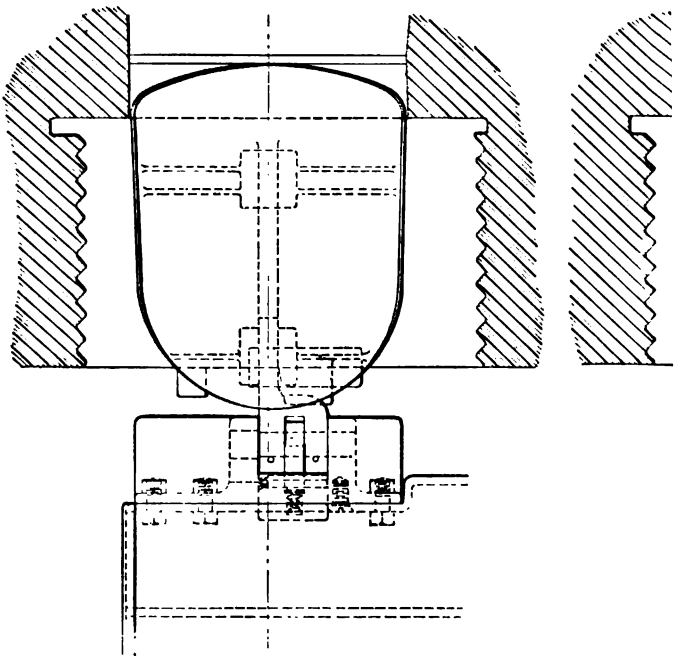
21. Miscellaneous fittings.—Placed in the turret-roof, well forward, are the three armored sighting-hoods. The trainer's hood,

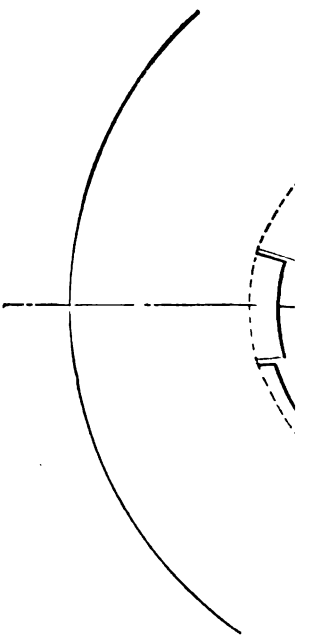
between the guns, contains the trainer's sight, an indicator showing the position of the turret in train, and the controller for the training-motors, with the circuit-breaker and the ammeters which measure the strength and direction of the current through the motors. The pointer's hoods are placed outside the guns, and each contains the telescopic- and the night-sight, the firing-key and the elevating-motor controller and circuit-breaker; there are no rest-lugs to this mounting and the pointer lays the gun to its loading-position by an indicator in the hood, which shows the position of the gun in elevation. A powerful smoke-fan and loading-platforms are installed. The communications are: speaking-tube and bell-pull from the handling-room, telephone connection to the hand-turning gear, dynamo-room and conning-tower, and electric range and battle-order indicators which transmit from the conning-tower.

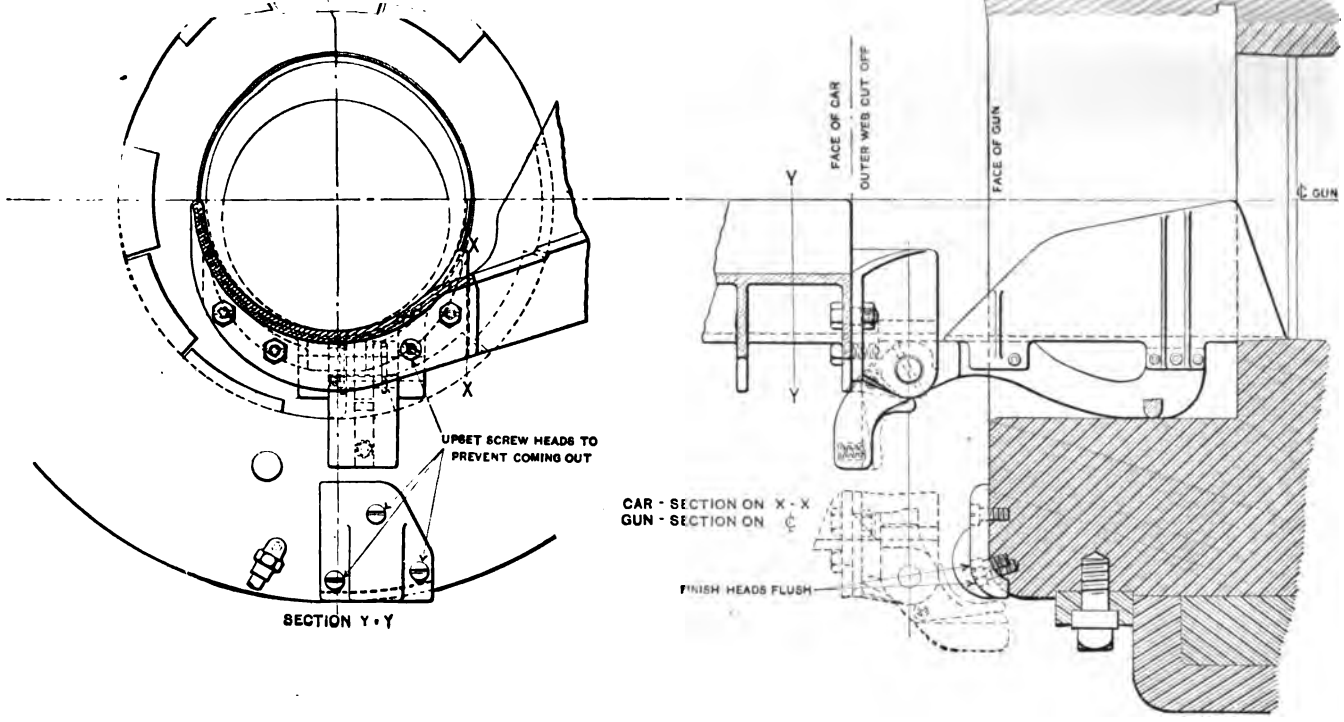
A Description of the Automatic Loading-Tray for 12-inch Ammunition-Hoist Mark V, and 12-inch Gun Mark III, U. S. S. Virginia.

Prepared by Lieutenant Joseph W. Graeme, U. S. Navy.

22. To the front-face of the flange of the bottom part of the lowest or shell-carrying chamber of the ammunition-hoist car is bolted, by four ¾-inch bolts, a bronze tray-bracket to which is hinged the tray-arm of manganese bronze which supports the tray proper. This tray-bracket carries two lugs for the hinge, and in addition a central lug between the two which contains a notch in its forward part for the latching-hook of the tripping-trigger which holds the tray in the vertical position. The loading-tray, made of manganese bronze and ribbed on the under side for strength, is, roughly speaking, a half-cylinder, the after portions of its sides being cut away slightly, to clear the ammunition-car when the tray is vertical. The tray carries on its under side two lugs, each of which is slotted longitudinally to receive the tray-arm, to which each is riveted. The tray-arm is secured to the rear-lug of the tray by one half-inch rivet and to the forward-lug of the tray by one half-inch and two 5/16-inch rivets.






UPSET SCREW HEADS TO PREVENT COMING OUT
SECTION Y - Y
FACE OF CAR
OUTER WEB CUT OFF
FACE OF GUN
℄ GUN
CAR - SECTION ON X - X
GUN - SECTION ON ℄
FINISH HEADS FLUSH

AUTOMATIC LOADING-TRAY, 12-INCH AMMUNITION-HOIST, MARK V.

When the tray is in position for loading, the tray-arm rests in the bottom of the lowest-blank of the screw-box, and the bottom of the front end of the tray rests on the bottom portion of the gas-check seat, for a longitudinal distance of 2.6 inches. The length of the tray proper is 17.75 inches, breadth over all is 14.30 inches, and its height is 8.75 inches, including the securing lugs on the bottom. Its inside surface is cylindrical, radius 7 inches, which is the same as the shell-chamber of the ammunition-hoist car.

23. The portion of the tray-arm in rear of the hinge-pin curves downward and to the rear (considering the tray to be horizontal in the gun) in roughly the shape of a pistol-grip, which designation will be used in this description. In a vertical slot in the pistol-grip is pivoted a tripping-trigger, roughly triangular in shape, the pivot being at one angle, the latching-hook at another, and a projecting trigger at the third. A small spiral compression-spring, housed within the lower part of the pistol-grip, forces the trigger-end outward, throwing the latching-hook tightly against the central lug of the tray-bracket. When the ammunition-car is being hoisted or lowered and the loading-tray is vertical, close up against the car, the latching-hook is held in the notch in the central lug of the tray-bracket by the tripping-trigger spring above mentioned. Secured to the lowest point of the rear face of the breech of the gun by three $\frac{5}{8}$-inch screws is a triangular steel pad with a raised cylindrical cam in its center. The purpose of this cam will become evident in the following description of the operation of the loading-tray.

24. Suppose the ammunition-car is being hoisted, the loading-tray is held latched in the vertical position by the tripping-trigger. In this position, the pistol-grip of the tray-arm is horizontal and projects forward. The trigger-end of the tripping-trigger is also horizontal and projects forward, being about 9/16 inch above the upper surface of the pistol-grip. As the ammunition-car rises, the trigger-end of the tripping-trigger strikes the under side of the cylindrical cam on the triangular steel pad on the gun, and is pushed downward against its spring until it is completely housed in the pistol-grip, its upper surface corresponding with that of

the pistol-grip. This motion swings the latching-hook clear of the notch in the central lug of the tray-bracket. The pistol-grip now being in contact with the cylindrical cam, and the car continuing to rise, the tray-arm and tray are rotated forward about the hinge-pin as a center, and, aided by its own weight, the tray assumes its final position in the screw-box, ready for loading.

25. As the ammunition-car is lowered, the lower edge of the forward end of the tray-arm slides along the bottom and out of the screw-box, the downward motion of the car causing the tray to rotate about the hinge-pin towards the vertical position. As the lower edge of the forward end of the tray-arm slides down over the flat portion of the triangular pad on the breech-face of the gun, the tray assumes the vertical position and the latching-hook of the tripping-trigger is forced by its spring into the notch in the central lug of the tray-bracket, thus locking the tray in the vertical position. (See Plate VIII.)

CHAPTER XVII.

8-INCH TURRET-MOUNT, MARK XII.

1. The 8-inch Mark XII mount is a hydraulic-recoil, spring-return mount, electrically operated and controlled; as installed on ships of the Pennsylvania class, it is in most respects similar to the 12-inch Mark IV mount described in the preceding chapter. Plate I is a vertical longitudinal-section; Plate II, a vertical cross-section with right-half showing the slide in section and left-half giving the interior of the turret in profile; Plate III is a plan in which one recoil-cylinder is shown in section. (The following description is complete only as concerns those parts that materially differ from the corresponding ones of the 12-inch Mark IV turret.)

2. The turret (1), six inches in thickness, has three sighting-hoods as in the turrets of the Arkansas class; the forward half of the roof, however, is sloped downward at a slight angle as shown. The *barbette* (2), extending down to the protective-deck, is from three to six inches thick, and, to economize in weight, the diameter is reduced, between the lower decks, so that the barbette is divided into three parts of different sizes; the lowest part is of so small a diameter that it is merely an ammunition-tube. The bases of the turret-mounts of most armored cruisers, and of some battleships, are usually protected in this way. The hand (3) and the electric (4) training-gears are installed inside the barbette at the level of the gun-deck. The cast-steel slide (5) is in the common form of a sleeve about the gun-body, and its trunnions (6) rest in seats on the tops of the deck-lugs (7). The two recoil-cylinders (8), each containing counter-recoil springs in three sizes, are both bolted to the *under*-side of the slide and their piston-rods are secured to a yoke about the breech of the gun.

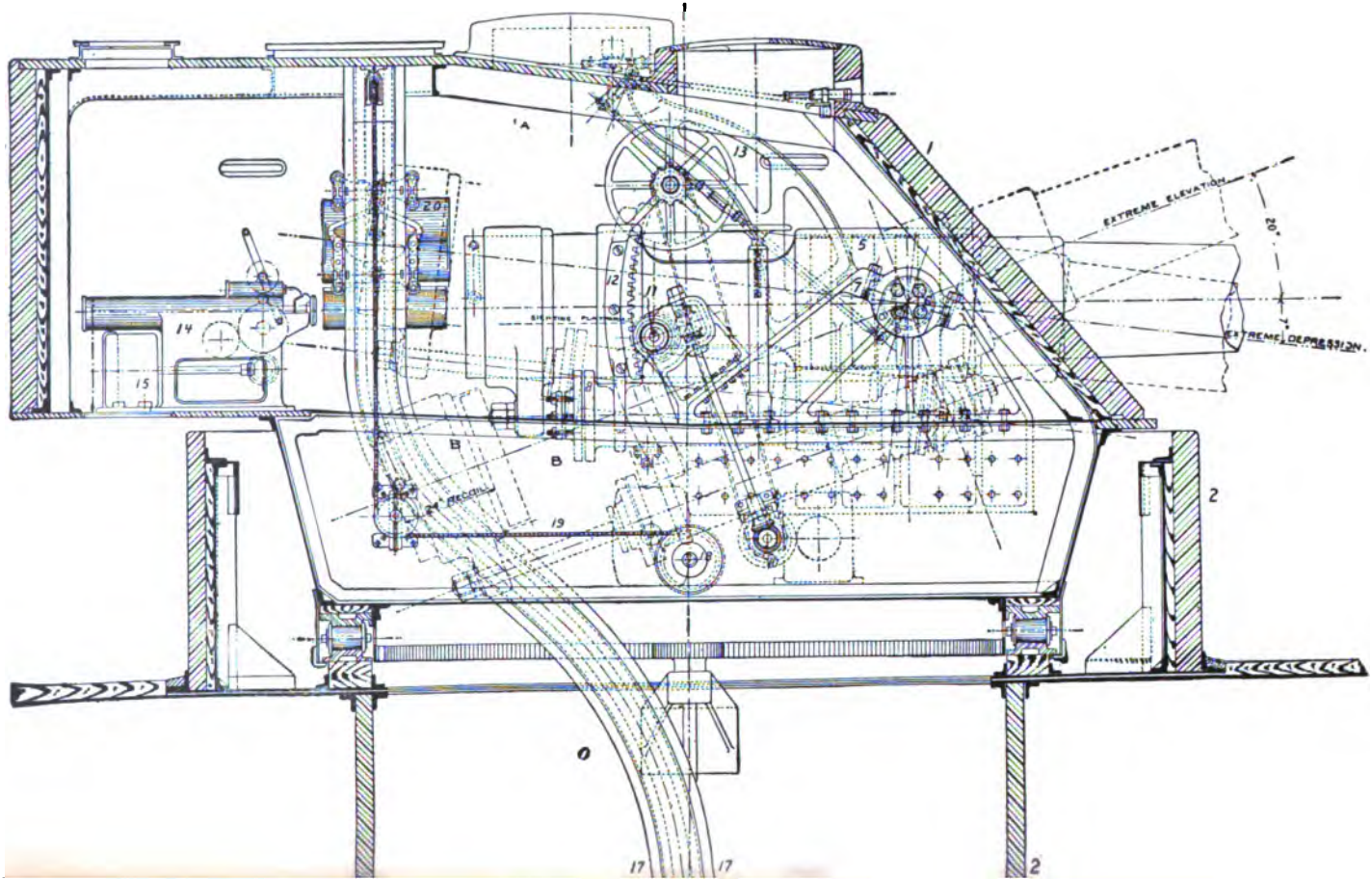
3. The elevating-gear of each gun is actuated by an electric-motor (9) placed under the turret-floor outside of the gun. The armature-shaft is geared to a cross-shaft (10) which is in turn

connected by shafting and worm- and bevel-gearing to elevating-pinions (11) at each side of the gun; elevating-arcs (12), in which these pinions gear, are bolted to each side of the gun-slide. A hand elevating-wheel (13), to be operated by the gun-pointer from his station, is connected by a chain and sprocket-wheels to the same cross-shaft that the motor is geared to. One of the pinions of the elevating-shaft is held between friction-disks which cushion the jump of the gun, by permitting the pinion to slip around between them, as described for intermediate gun-mounts. The disks are set up by a heavy nut, accessible from one side, and, when properly adjusted, they will slip at each fire enough to change the position of the gun in elevation a small amount.

4. The rammers (14) are of the chain-telescopic-type, driven by motors (15) placed beneath the rammer-casing. The rammers work in about the same manner as do those of the Mark IV 12-inch installation; the different sections, however, are not concentric and the driving-chains are placed on their tops, giving the rammer better support when extended. The spring buffers are also arranged differently; that for shocks in running out is on top of the casing as shown; the other, for shocks in withdrawal, is inside the innermost section. The loading-position is at level.

5. The ammunition-hoists are worked by 8 H. P. motors (16) installed beneath the turret-floor near the elevating-motors; the motors gear with shafts, each of which bears on its inner end the drum (18) on which the hoisting-cable (19) is wound. This cable, after passing over leaders, leads down and is secured to the ammunition-car (20). The magazines and shellrooms open into a common handling-room and the ammunition-crews, with the entire turret installation, are under the immediate command of the turret-officer. Because of the restricted size of the lower part of the barbette or ammunition-tube—the diameter is fifty inches—it was not practicable to design a car that would hoist the projectile directly to the loading-position. As at present designed, the car is hoisted to a fixed position, after which the projectile compartment is swung over by hand into the loading position.

6. The ammunition-car (as shown on Plates IV and V, it is slightly different from that of Plate II) is held to the guide-rails


EXTREME ELEVATION
20°
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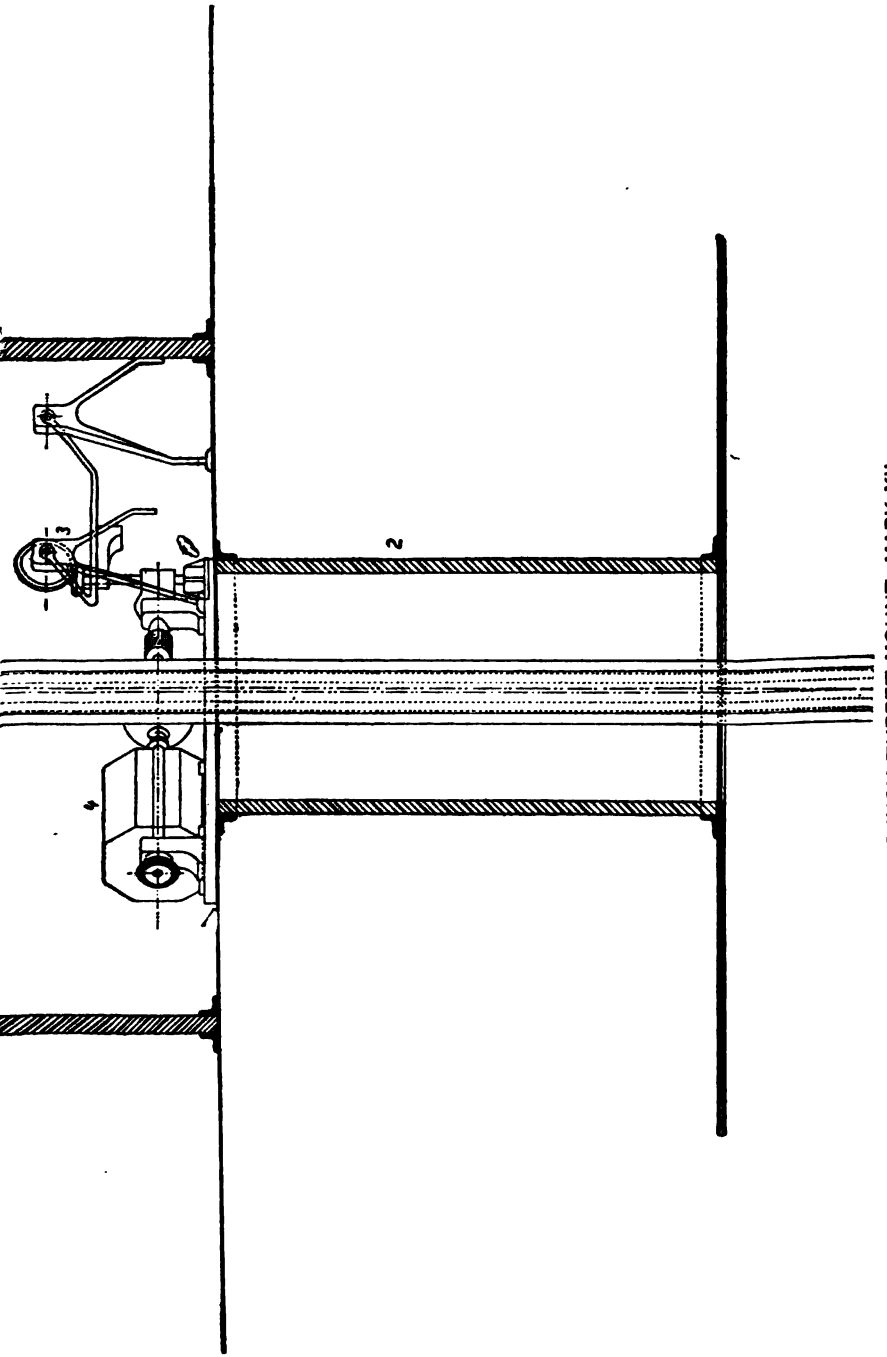
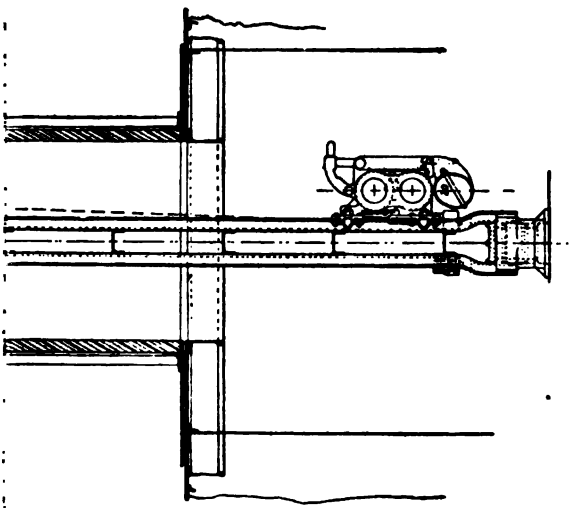


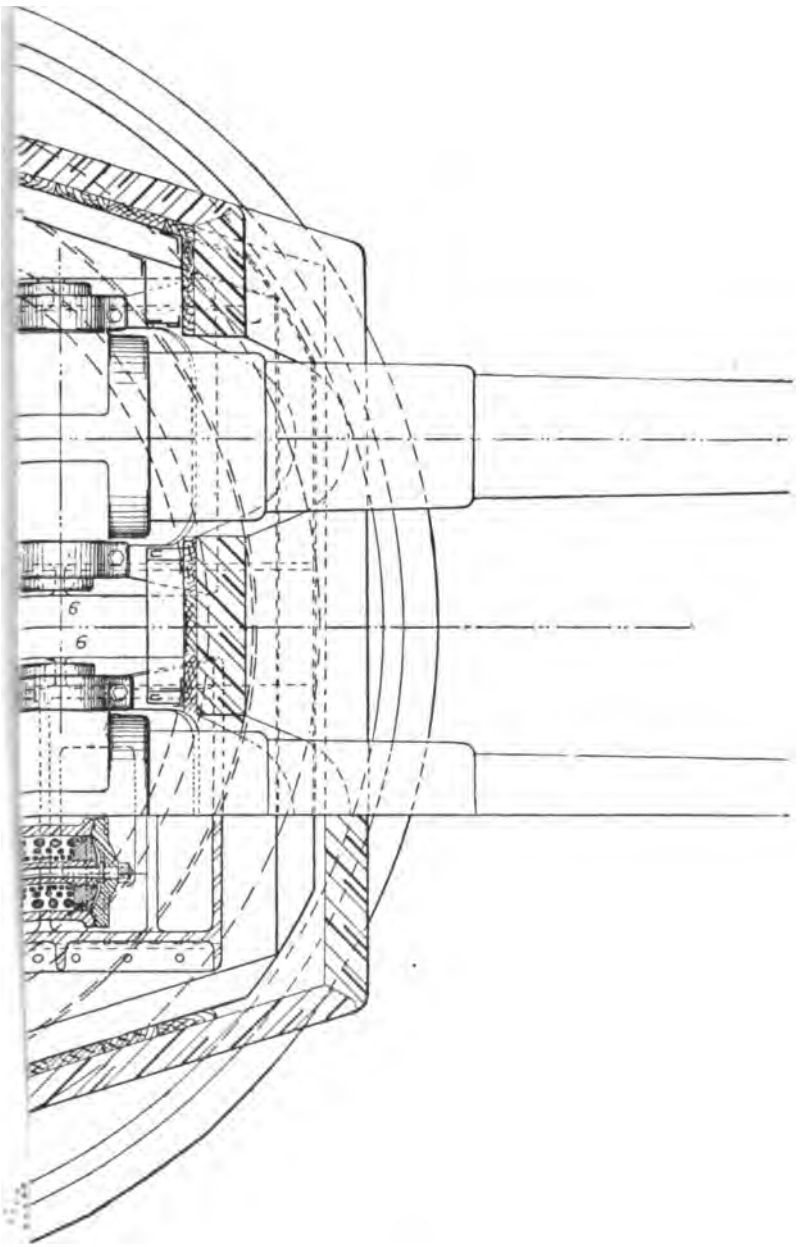
8-INCH TURRET-MOUNT, MARK XII.

(19) by double rollers that embrace the rails on three sides. The hoisting-cable is secured to a short bell-crank lever (20), which is held up as long as the weight of the car is on the cable; should the latter break, the spring (21) will draw the end of the bell-crank downward and, by the connecting-rods, force the lower ends of the pawls (22) outward and the car will be caught and held on the lugs, which are shown, on the inner edges of the guide-rails. The two sections of the powder-charge, both retained in place by one powder-catch (4), are hoisted in the upper compartments (2) and (3); it is intended to transfer the powder from the car to the gun by hand, and the front ends of (2) and (3) are partially closed. The projectile compartment (1), not of the same casting with the upper compartment, is pivoted to the upper part of the car by the long bracket-shaped lever (6) and during loading is handled as follows: The car having been hoisted up to the stops, one of the gun's crew grasps the handle (9) and draws it toward him. This handle first swings out on its pivot, disengaging the hook (8), until brought up by the lug (10), whereupon the shell-carrier (1) swings outward on the pivot (11) until the pawl (7) engages the upper end of the lever; in this position the projectile is held in line with the bore and in front of the rammer. The shell-latch (5) having been raised, the chain-rammer sends the projectile home, is withdrawn, and the pawl (7) is raised, permitting the shell-carrier to swing back into place.

7. **Knife-edge trunnion-bearings** (Plate VI) are fitted to many guns of 8-inch caliber and upwards to relieve the friction of the trunnions, caused by the great weight of the gun bearing on the trunnion-seats, and thus require less powerful elevating machinery. The small trunnions (1) are screwed into the faces of the ordinary slide-trunnions (2) and their lower sides are faced away, forming knife-edges nearly in prolongation of the center line of the slide-trunnions. The supporting-bar (4), into which is dovetailed a very hard steel face (3), is so adjusted by the bolts (5) that the knife-edge is given a firm bearing, taking the weight of the gun. When not in use, the supporting-bar should be lowered until the gun rests entirely in its ordinary trunnion-seats. To prepare for firing, or for exercise, the bar is leveled and raised until a thin piece of paper can be inserted be-



8-INCH TURRET-MOUNT, MARK XII.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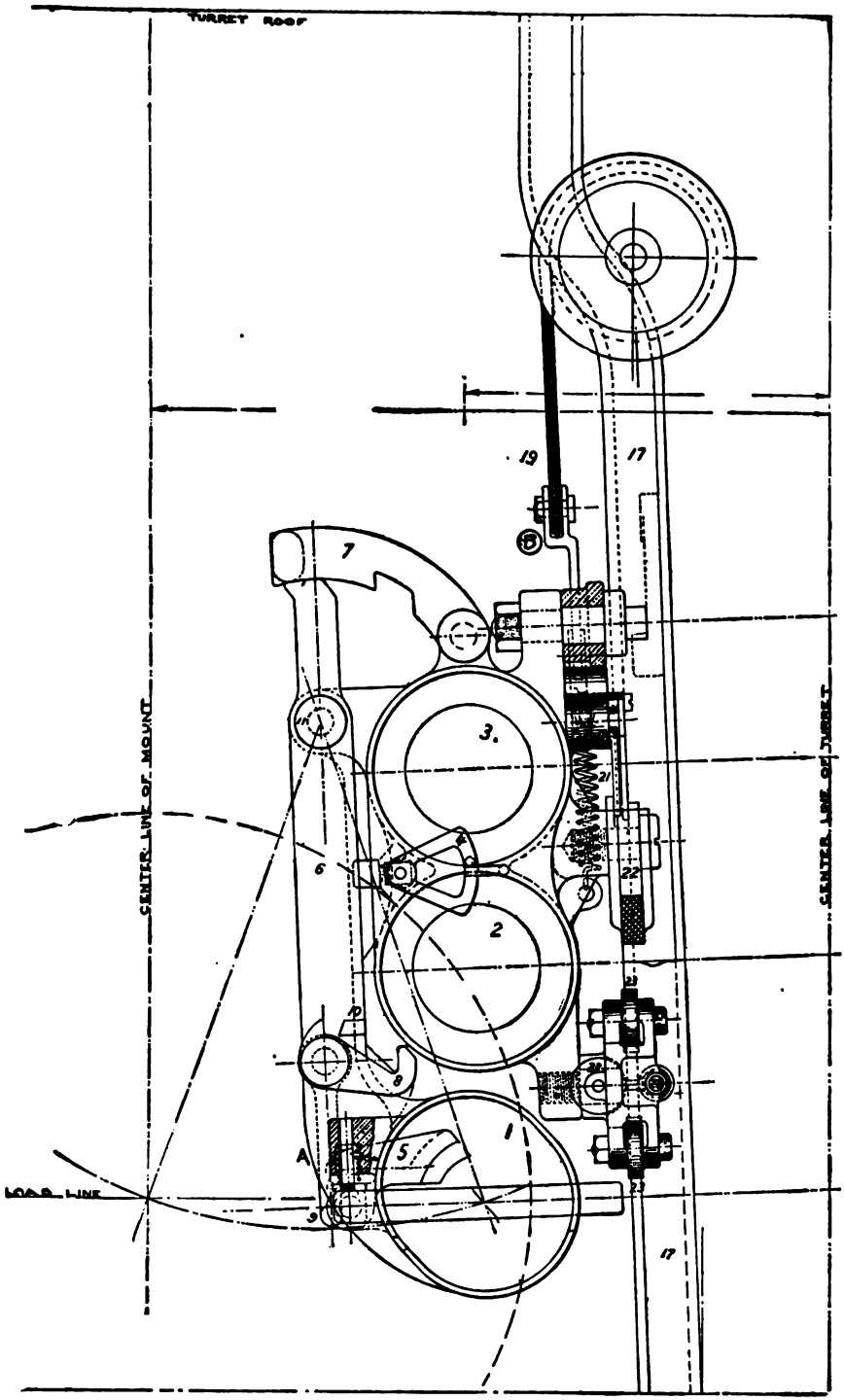
neath (2); the elasticity of the bar (4) permits the greater part of the shock of discharge to act on the trunnion-seats. This device is older than that described in Chapter XIV.

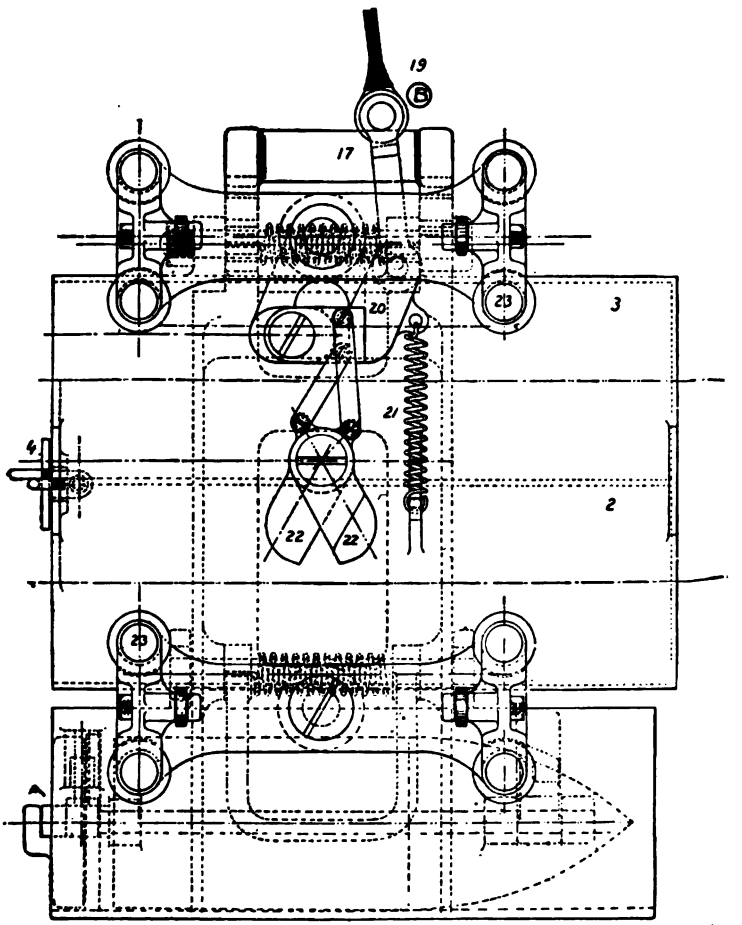
8. Counter-recoil checks for turret-mounts.—Because of the necessity of mounting turret-guns with their trunnions close to the gun-port and thus keeping down the area of the port-openings for required arcs of elevation, it is not practicable to have front cylinder-bonnets of sufficient length to accommodate the "dash-pot" checks employed in the intermediate mounts. The device for the 8-inch mount, Mark XII (Plate III), which is in general use, is the same as the "dash-pot" in principle, but arrives at the result without lengthening the cylinder-bonnet. In the front end of the piston-rod is a counterbore that receives a grooved or tapered rod which is firmly screwed into the front bonnet. During recoil, the piston-rod is drawn to the rear and the counterbore fills with the recoil-liquid; then, as the gun returns to battery, this liquid is forced out again by the plunger, as it enters the counterbore, and the counter-recoil is cushioned.

NOTE.—The original design of the 8-inch mount, Mark XII, for Pennsylvania and class, was never installed on board ship, changes having been made before the mount was completed. The sights and sighting-hoods are moved forward of the center-line or axis of the turret, and the hand elevating-gear is moved to a more convenient point under the hoods. The ammunition rammer is driven by a silent chain-gear. Controllers, rheostats, circuit-breakers and motor-generator sets have been located. A frictionless trunnion-bearing, and a gas-ejector have been added. The turrets for the Louisiana, Connecticut and Vermont and class are somewhat different in shape from those of the Pennsylvania and class. The slope of the roof is greater, and the guns set lower in the turrets; otherwise the mounts are similar.



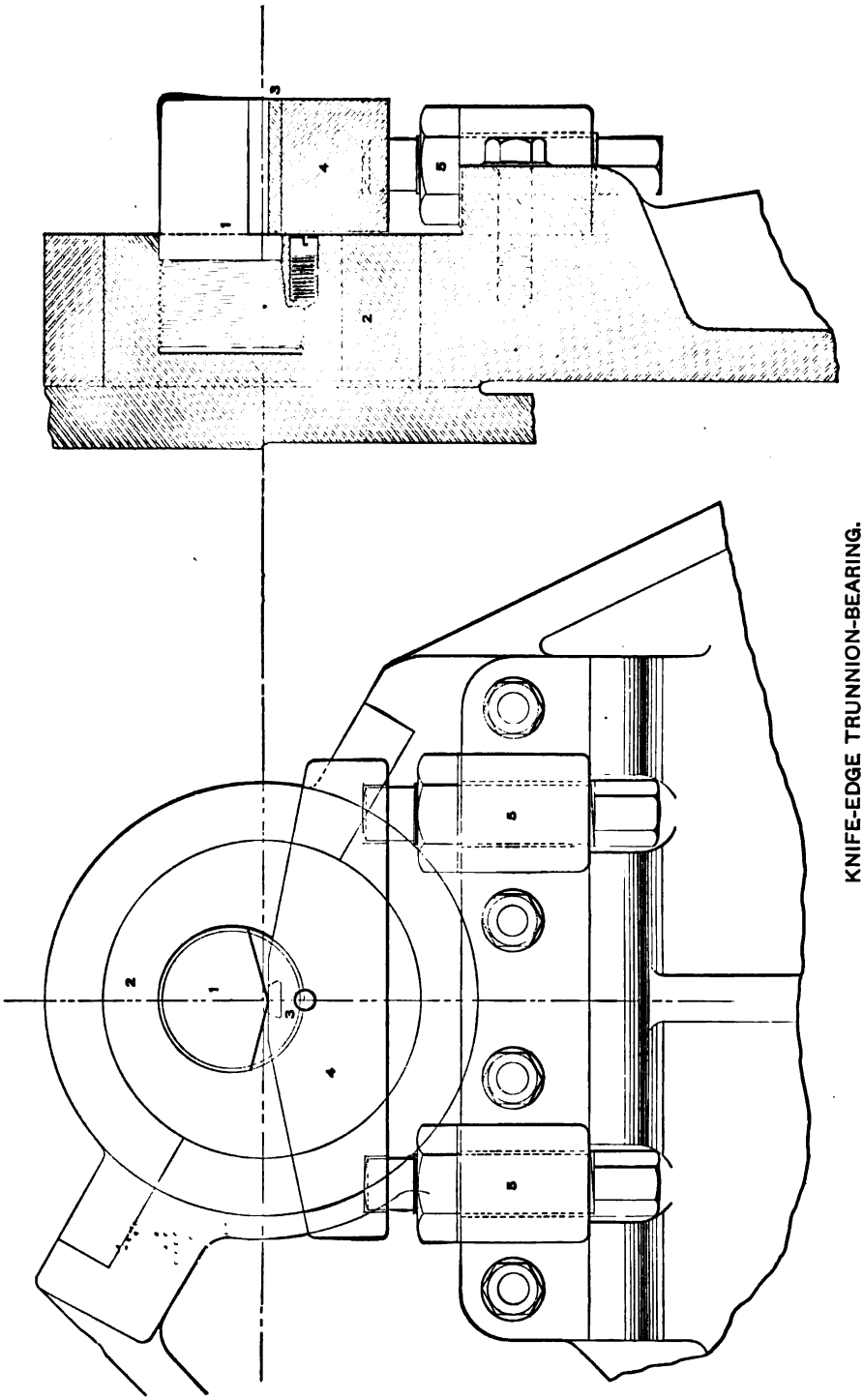
AMMUNITION-CAR.

Rear View.



AMMUNITION-CAR.

Longitudinal Profile.



KNIFE-EDGE TRUNNION-BEARING.

CHAPTER XVIII.

FORMS OF TURRET ARMOR, BALANCING OF TURRETS, LOADING-POSITIONS, ETC.

1. There are three distinct methods of protecting heavy guns that are worked by machinery:

(1) *By simple barbettes* (Fig. 1) with all armor stationary. The barbette, either round or pear-shaped, encloses and protects

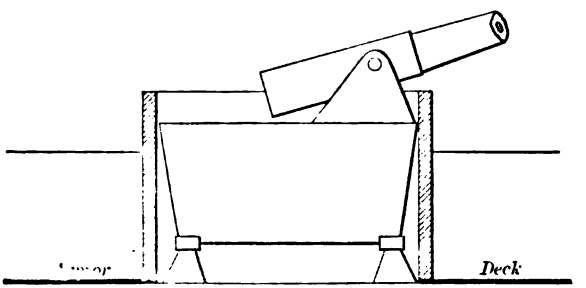


FIG. 1.

all the gun-working machinery but the guns themselves are entirely in the open and above the top of the armor. The turntable is usually covered, at the level of the barbette's top, with a thick roof; large openings must be left in it to permit serving the guns. Many of the crew are sheltered from direct fire by the guns and the roof of the turntable but there is necessarily much exposure to splinters. This form of protection is found on many of the early battleships of the British Navy, but it is no longer in favor; the guns load at a considerable angle of elevation.

(2) *By turrets proper,* in which there is no stationary armor except a narrow ammunition-tube (Fig. 2). The turret has great height, comparatively, and rolls on a path on deck or built directly on the ship's structure. The floor is made thick as a protection from shells exploding underneath. This method gives excellent

protection, both to the mounting and to the personnel. However, the weight of armor which must be trained is very great; an even more serious defect is that the rollers and roller-paths are usually badly exposed, making the turret extremely likely to be jambed by gun-fire. This form was a favorite with the Russians, but has been abandoned for their later ships. Some of the U. S. low-freeboard monitors afford a still more primitive type. In these, the armored ammunition-tube is omitted and the ammu-

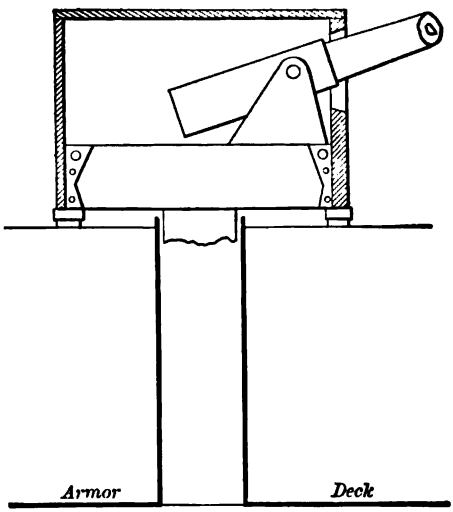


FIG. 2.

nition-hoist is only protected by the side armor and the armored deck; this is the arrangement in the original Ericsson monitor.

(3) *By turret-barbettes,* the type now generally accepted to be the best and that which is found in all large ships of the U. S. Navy which carry heavy guns. (For illustration, see the chapters on turret-mounts.) It is a combination of the other two forms, retaining the advantages of each and, as far as now seems possible, eliminating their defects.

2. Many considerations enter into the question of the number of guns to be mounted per turret and on it there are great differences of opinion. It can readily be seen that, for equal protection,

a much smaller weight of armor is required to protect two guns if they are in the same turret than if they be mounted in separate turrets. This principle has been extended farthest by our Navy, in those ships which have 8-inch guns in double turrets, superimposed on the main turrets. This plan saves the entire weight of the barbettes and ammunition tubes for such 8-inch guns. With the possibility of better fire-control, it appears that this saving in weight is the only advantage that double or superimposed turrets have over single turrets.

3. Manifestly, a battery in single turrets has its guns more isolated and should be capable of enduring about twice as many hits before being silenced than if mounted in double turrets. Two crews in a double turret ought to be able to serve their guns with but little or no interference from each other. As for the pointers, however, there *is* interference; it is held by many to be so great that the fire from a single turret will be very nearly, if not quite, as effective as that from a double turret. The shock and recoil of one gun of a pair always displaces the turret enough to throw its mate entirely off the target; it is evident that the more rapid the fire the more serious will be this interference in pointing and that there should be but little with slow-firing guns.

4. At present, the best practice seems to be to mount the largest guns, such as the four 12-inch, in double turrets amidships; and such sizes as 8-inch, 9.2-inch, etc., of the intermediate battery, in single turrets on the broadside at about the same height above the water.

5. The disadvantages of the round turrets in which the hydraulic turret-mounts of the U. S. ships are installed are as follows:

(1) The diameter must be great enough to give room in rear of the guns for performing the loading operations, and for the recoil, etc., but so great a *transverse* dimension is not necessary and much waste space is left at the sides, in addition to the disadvantage of presenting a broad target.

(2) The barbette must be of even greater diameter, to permit the turret to rest inside of it, affording more waste space and adding to the uneconomically disposed weight of armor.

(3) The guns and their mountings must be installed close to the

gun-port, and an "unbalanced" turret, whose center of gravity does not coincide with the center of rotation, is the result; the center of gravity of all the revolving parts of the Indiana's 13-inch turrets is about four feet from the center of rotation.

(4) When both of these turrets are trained abeam on the same side, the effect is the same as moving several hundred tons four feet from the center line and giving the ship a list that immerses the side armor on the engaged side and places her in an unfavorable position for receiving fire.

(5) Also, in an unbalanced turret of this kind, greater power is required in training, particularly if the ship is listed and the turret moving "up hill," and more powerful motors must be installed; the control of training-machinery is difficult, since the turret will run "down hill" with ease and be made to revolve in the other direction only with great effort. If hydraulic training-motors are used, this last defect is not as serious, since the tendency is for the motors always to have the same speed for a given valve-opening even if called upon for variable efforts.

6. Balanced turrets.—Beginning with the Iowa, the "balanced" turret has been installed in the U. S. Navy. The barbette is round but of smaller diameter and the turret is entirely above the armor instead of extending below the upper edge of the barbette. The turret is oval and overhangs the barbette in rear of the guns enough to bring the center of gravity of the moving parts into coincidence with the center of rotation. Weight is saved by these balanced turrets, the size of target is reduced, and the training-motors, having the same effort to make under all conditions, run more smoothly and are more easily controlled.

7. The fronts of the earlier turrets are all vertical cylindrical surfaces, make large targets, and have large unprotected port-openings. In those of later design, the front is plane and inclined from 40° to 50° to the vertical; for the same maximum elevation, the port-opening may be smaller than in a perpendicular front. The sides and rear of turrets are slightly thinner than the front which is usually of the same thickness as the barbette. The front of the turret is necessarily the most vulnerable part of the installation because of the port-openings. Until recently, no satisfactory port protection has been devised; it is likely that a

thick shutter will be attached to the gun-slide so that it slides up and down in strong guides on the inner surface of the armor as the guns are worked.

8. In some cases, the roof of the turret is not horizontal but is sloped downward from the rear at a small angle, making part of the target too oblique for projectiles to bite upon. The wooden backing which was at first fitted behind turret and barbette armor is no longer being used; it is retained for the side armor.

9. As a result of a disastrous handling-room explosion, the floors of turrets are to be made, as nearly as possible, continuous with automatic doors for the passage of the ammunition cars. This floor in French turrets is armored. In all turrets, automatic cut-offs stop the turning-motors as the limit of train in either direction is approached.

10. Loading-positions.—In our navy, all turret-guns are loaded in any position in train and in but one position in elevation —except in the pneumatic turrets of the Terror, which load in any position, and a few 8-inch turrets using only hand-rammers, which load in any position *near* the level point. Formerly, many turret-guns, particularly those of foreign navies, could be loaded in but one, or at best two, positions in train, and the turrets were laid in those positions before the rammer could act or the ammunition be hoisted; a great waste of time is involved in such systems of loading. It is possible, as has been done abroad, to install the rammer on an arm extending rearward, from the gun-slide, lock the ammunition-car to the slide as well, and thus load in any position,—since car and rammer will follow the breech of the gun and keep in line with the bore, irrespective of any change in elevation; as can readily be seen by an inspection of the longitudinal section of a turret, either the height of the turret or the diameter of the barbette must be greatly increased to make the installation of this system possible. If the loading-position is fixed at level, as in our later turrets for instance, the gun may be pointed as soon as the rammer is withdrawn after loading the last powder sections and, during the few seconds occupied in completing the loading and sending the car down, the target should be picked up and the pointer ready to fire as soon as he receives the "ready" signal. Thus, little if any decrease in the rate of fire should be occasioned

by the restriction of one loading-position in elevation, and the weight of armor is kept down by adhering to it.

The Respective Advantages and Disadvantages of Steam, Pneumatic, Hydraulic, and Electric Motive Power for Turret-Mounts.

11. The rapidity and accuracy of fire of a turret-gun are controlled to a large extent by machinery—the elevating and training-gear, the ammunition-hoist, the rammer, etc. The character of the motive power, by which this machinery is operated, materially influences the general efficiency of the mounting and there is much difference of opinion as to which power is most suitable. Summing up the views of ordnance engineers of this and of foreign countries, the advantages and disadvantages of the four kinds of power are put forth as follows:

12. Steam.—Steam engines, with their pipe-leads, valves, etc., which radiate much heat, will, even when carefully designed, greatly overheat the lower decks and compartments which are difficult to ventilate; in addition to this, they are next to impossible inside a turret, owing to the danger of scalding the crews in the likely contingency of joints being damaged and pipes broken in action. The only practicable utilization of this power is for training, as is done in the U. S. hydraulic and the earlier 8-inch turret-mounts. But, because of the difficulty in getting control,—through a long system of levers that invariably has much lost motion,—that will give slow movements and quick starting and stopping powers, steam engines are not suitable as turning machinery. Besides, in consequence of the intermittent nature of the work done, there is likelihood of complete failure, due to the condensation of steam in the cylinders and long pipe-leads. This may be overcome by a properly designed system of draining, but it would add complications. The sole advantage of steam-actuated machinery lies in the simplicity and lightness of the installation.

13. Compressed air has one great advantage compared with steam:—no return pipe is required, as all motors may exhaust into the atmosphere, materially assisting ventilation, but the noise of the free exhaust is objectionable. Unless all the motors are made

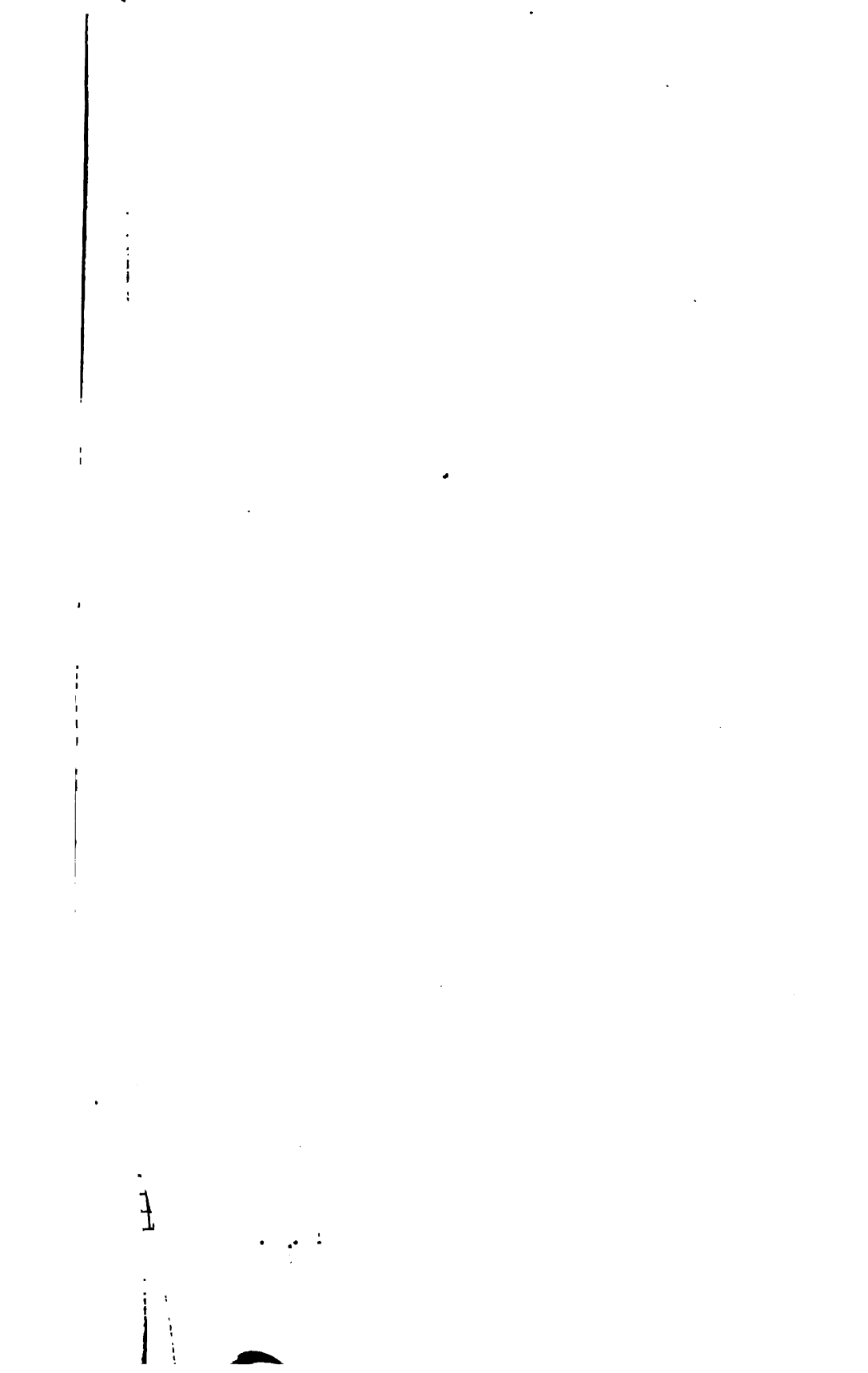
very large and cumbersome, compressed air must, to obtain the necessary power, be worked at a very high pressure, and a damaged pipe might therefore cause a serious explosion. The air compressing machinery must be large and heavy or be run at a high speed; thus, if the air be compressed only to a reasonably safe pressure, weight and power must be uneconomically used. The control system is necessarily similar to that required by steam and is nearly as inaccurate; both steam and air are inherently defective because of their compressible elasticity.

14. Hydraulic power, the favorite in the British navy, is used in U. S. hydraulic turrets as previously described and in a few turrets for training purposes as well; it is the only power that approaches the suitability of electricity as a motive power, being its very close rival for the gun-pointing motors. The pipes, giving out no heat, may be laid anywhere; the system is economical and not of great weight; no explosion is possible; if damage occurs, the exact place can be readily discovered; and it may be utilized to return the guns to battery. Its *disadvantages,* when compared with electric power, are that any damage is difficult of repair and hand-power gear is not easily substituted for hydraulic motors; the enormous pressures make joints difficult to pack tightly and they are all likely to leak badly after a few shocks and cause much inconvenience, to say the least, in the handling-room; with these high pressures, bad water-hammers will occur when a motor is suddenly stopped and, even when handled by experienced men, they frequently give out. Either the motors must be installed near the control stations or mechanical connections, involving lost motion, must be employed; when these difficulties can be met, hydraulic power is excellent for elevating and training. The motors are of a nature to be closely connected to gun and turret with little intervening gearing; it is a suitable power for coping with the great inertia of the moving parts and the braking effect is good. In British naval turrets, electrical devices are frequently employed in the control systems of the hydraulic pointing-motors which are so extensively used.

15. Electric power is used for all motors in the turret-mounts of recent U. S. ships to the exclusion of any other; electrical machinery for this and many other purposes has had greatest develop-

ment in this country. The ship's generators, which are necessary for other purposes, are utilized and the weight of pumping-machinery and piping is saved; the dynamos are always running, and power for at least part of the turret machinery is always available. The wires may be laid anywhere and a broken connection is readily repaired; no explosions are possible and the motors are never dangerous or even objectionable. The control station may be at any distance from the motor, which may be tucked away in a safe secure place, utilizing waste space and giving room in the turret. The character of the motors makes substitution of hand-gear a simple matter. Any motor may be reversed, when running at full speed, without injury; safety devices which make damage by improper or inexperienced handling nearly impossible may be readily installed. The motors are extremely sensitive to control. The only *disadvantages* are: that the installation is rather heavy; difficulty and loss of time may be experienced in discovering the cause of a failure although the damage may be trifling and admit of easy repair; gear-trains are required between the armatures of some of the motors, particularly the pointing-motors, which are necessarily elastic and involve lost motion.

16. The following table gives statistics for U. S. turret-ships: This table was first compiled in 1904, and at that time contained statistics of all turrets then designed—in so far as the details had been decided upon.



CHAPTER XIX.

BATTERY COMPOSITION AND ARRANGEMENT.

1. Composition.—The composition and arrangement of ships' batteries is perhaps a matter of more rapid and constant evolution than any other in the whole subject of Ordnance. In matters of detail, such as breech mechanisms, projectiles, powder, etc., the practice of all the great navies is much the same, but, in this broader subject, the widest divergence of opinion exists among experts charged with the direction of such affairs. It is needless to say that the whole design of warships depends upon the number, size, and method of mounting the guns which they are designed to carry. The proportion of displacement to be devoted to armament, ammunition and ordnance stores having been decided upon while working out the preliminary design of the projected ship, it remains to determine the number, sizes, and arrangement of the guns of her battery with the view of delivering the most *effective fire,* and of obtaining the best protection consistent with the weight that can be given to armor.

2. Within limits, for a given weight of armament, the smaller the caliber of the guns, the greater will be the weight of projectiles that the battery will deliver per minute; or, to express it differently, 100 tons of secondary-battery guns will fire a greater weight of metal in a minute than will 100 tons of main-battery guns, and the muzzle velocity may be the same for all sizes. However, there is neither space enough nor crew enough for the great number of small guns that such a policy would call for. Besides this practical consideration, it is the heaviest *effective fire* that is sought, and not merely the getting overboard of great quantities of metal that may do nothing more serious than to spatter the enemy's armored side even if it can be directed with sufficient accuracy to insure hitting at the long ranges likely to be forced upon us.

3. The policy of most navies at the time of writing (to which there is but little opposition from authoritative sources) is to divide the assigned weight of battery for all types of ships into the largest guns that can be readily handled, keeping in view the gun-power of the probable enemy in the case of each type. For ships-of-the-line, the great extent and thickness of the armor now carried by the probable enemy—the modern battleships of all navies—forces the big-gun policy, because a gun below eight inches in caliber will not do effective work against heavy armor under battle conditions.

4. The soundness of this policy is shown by the following advantages: (1) better protection for guns; (2) fewer expert gun pointers required; (3) better communications and easier fire control; (4) an easier system of ammunition supply, which is also simplified if but two or three calibers are found in the same ship; (5) increased accuracy of fire over small guns, because of higher velocities and flatter trajectories. It is the same policy that in 1812 opposed the 18-pounders of the enemy's frigates with our 24-pounders on slightly heavier vessels, and was a factor that largely contributed to our success. The tendency now is, therefore, to mount on all armored ships nothing but heavy guns *in turrets,* and an adequate secondary battery of which the largest gun will be of 3-inch caliber.

5. Arrangement of battery.—In determining the battery arrangement of a ship there must be kept in mind:

(1) The conflicting problems of mounting the guns at a fair height above the waterline, where they will not be interfered with by seas, and at the same time retaining the proper stability of the ship.

(2) The facility of ammunition supply.

(3) The necessity for gaining the best protection for the guns on the allowed weight of armor.

(4) The desirability of large arcs of fire for all guns without undue "interference"—the blast of any gun seriously disturbing the crew of another. The latter problem is the subject to be now considered as concerned with the battery arrangement of battleships and armored cruisers.

6. In the present development of naval tactics, it is evident that the favorite formation for fleet actions is in column, or "line ahead," as it is sometimes called; this and the fact that a ship is several times as long as she is broad and that we cannot, without great sacrifices, have many tiers of guns, makes it inevitable that most of the guns shall be mounted in broadside—able to fire over a small part of the circle on each beam. The same conditions obtained on the sailing battleships, and the largest of them were able to point as many as 60 guns on the broadside, but they could rarely fire dead ahead with more than four, or perhaps six; structural requirements for one thing, then, forced such a condition. In steam ships, the structural difficulties can be overcome to a great extent; but the possibilities in the case are approached only to a moderate degree, on the principle that, while *end-on fire* is valuable, what is really essential is *broadside-fire* with the greatest number of guns possible.

7. It may readily be seen that a gun mounted amidships, able to fire on both sides, is practically two guns; when first so installed, they were called *pivot guns* and were the most important pieces in the battery; this is still the case. Theoretically then, the best arrangement, as giving the heaviest broadside-fire, is with all the guns on the center line and able to fire on both sides. Practical considerations such as boat-stowage, fire- and engine-room hatches, etc., prevent this arrangement and we are limited to two positions, at bow and stern, for "pivot" guns. But we make the most of it by installing a turret at each of these two positions, each containing two of the heaviest guns in the battery. The only practicable extension of the principle is to use another middle-line turret-position, as has been tried in a class of German battleships which originally carried six 11-inch guns each; also the U. S. battleships which have turrets containing 8-inch guns, superimposed on the 12-inch or 13-inch turrets. Guns of 8-inch or larger caliber, other than those in the main turrets, are as a rule installed on each side in turrets, which, next to the midship guns, have the largest arcs of fire.

8. Intermediate guns.—Coming next under consideration in the assignment of gun positions, is that part of the battery known as the "*intermediates*"—guns of from 4-inch to 7-inch caliber.

Their mounts are generally hand-worked and they are mounted in broadside in armored positions. The favorite system is to mount four that may fire from dead ahead to a few degrees abaft the beam, the same number firing from right astern to a few degrees forward of the beam and the remaining ones with arcs of about 100 degrees on each beam.

9. Secondary battery.—The principal purpose of the secondary battery is to repulse torpedo attack; 3-inch guns if protected may be relied upon also to do some effective work against any variety of ship; but small guns will probably be put out of action long

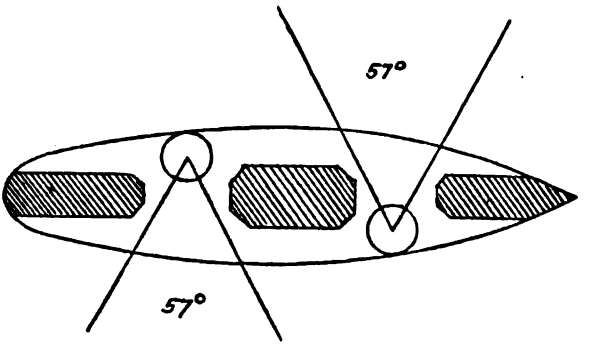


FIG. 1. ART. 11.

before the enemy is within their effective range. Being then the least important guns in the battery, they are given whatever space is left after the main battery is arranged; they are placed under the main deck in the unarmored ends, along the superstructure rail, on the bridges, and in the fighting tops. In their proper rôle, meeting torpedo-attack, they will not be subjected to severe gun-fire and hence need not be protected; in battle, they need not be manned, save perhaps with the exception of the 3-inch guns, which are often protected by thin armor.

10. The requirements for an unarmored ship's battery are, in the main, very similar; these ships have no turrets and their main-battery guns are all about the same in size. As a rule, two of the largest guns are installed amidships in bow and stern, and have the same large arcs of fire as turret-guns—250 degrees or more; all

the other guns are arranged, as far as possible, like those of the armored ships.

11. Two or three decades ago, the idea was prevalent that the advent of steam propulsion had set tactics back to the days of Grecian supremacy on the seas; it was held by many, in whose minds the battle of Lissa was fresh, that the ram was the supreme weapon and that, as with the fighting galleys, the best defensive and offensive fleet formation was in line abreast. As long as the idea held sway, end-on fire, particularly ahead, was sought after at the expense of broadside fire, and ships were built which were able to fire as many guns ahead as on the beam. The "echelon" arrangement of the two main turrets was then a favorite one. The figure, which is a plan of the Maine that was blown up in Havana harbor, shows it. The upper works are cut away to permit each turret to fire ahead and astern and, for a small arc, across the deck. This fallacy endured for but a short time, however, as it was found that the arrangement gives a fire on bow or quarter from only one turret; column being the best fighting formation, this restriction of broadside fire would prove very costly. Besides, there remains no good place for the large intermediate battery needed, as the blast of the turret-guns, when used as designed, makes such positions untenable; the superstructure will not stand the blast of the turret-guns when fired in line with the keel, or across the decks. The Texas is the only armored ship in the U. S. Navy with the echelon arrangement.

CHAPTER XX.

FIRING-ATTACHMENTS.

1. In United States naval guns, the term "*firing mechanism*" is used to designate that part of the breech mechanism which directly explodes the primer and thus fires the gun. The "*firing-attachments*" comprise those appliances, fitted to the gun and mount, which put the firing mechanism in operation. The lock-lanyard, electric-firing battery, wires, terminals, firing-key, etc., are "*attachments.*" The two terms, "*firing mechanism*" and "*firing-attachments,*" must not be confused.

2. Two methods are employed in firing guns—by electric- and by percussion-primers. The latter method is most suitable, and is used exclusively, for the small guns of the secondary battery, while the first method is mainly used for the larger guns, it being more satisfactory for the following reasons:

(1) **Electric-primers** are less liable to cause accidents than are percussion-primers containing fulminate of mercury; the electric-firing circuit may have as many "breaks" as are considered necessary, which are automatically closed only when the gun is in all respects ready for firing, thus making premature discharge impossible; the primers contain no explosive of the sensitiveness of the fulminates and consequently permit rougher handling; serious explosions abroad are said to have been caused by the blow of the breechblock, while being closed in the ordinary manner, against the base of the percussion-primed cartridge-case.

(2) Electric-primers shorten the "firing interval," or the time that elapses between the instant the gun-pointer wills to fire and the instant the projectile leaves the muzzle. This interval, which on the average is about 3/10 of a second, has two factors: (1) the personal factor (which is much the greater), depending on the pointer's quickness and nerve, and (2) the time consumed by the travel of the projectile along the bore and by the mechanical

action of the firing devices. With electric-primers, the pointer's muscles act through a less distance and the passage of the current is more nearly instantaneous than is the action of the lock-lanyard, sear, hammer, etc., and this part, at least, of the firing interval is reduced. Besides this advantage, the effort required to operate the firing-key is very slight, the pointer may keep his hand upon it with ease and need never take his eye from the sight; if, while using percussion-primers, the pointer's station is far from the breech of the gun it may be necessary for another man to pull the lanyard, at his command.

3. (1) **Percussion-firing** for the main-battery guns is now retained only as an alternative when the electric current fails. Up to 1899, separate primers were employed for the two kinds of firing; and the changing of primers also necessitated changing from percussion- to electric-firing mechanisms and attachments, or vice versa; the 4-inch R. F. gun with Fletcher breech mechanism, shown on Plate I, is of this variety, and the ammunition for it is either percussion- or electric-primed—both kinds being carried.

(2) *All guns of 3-inch caliber and below* are now fitted with percussion-locks and percussion-primers only.

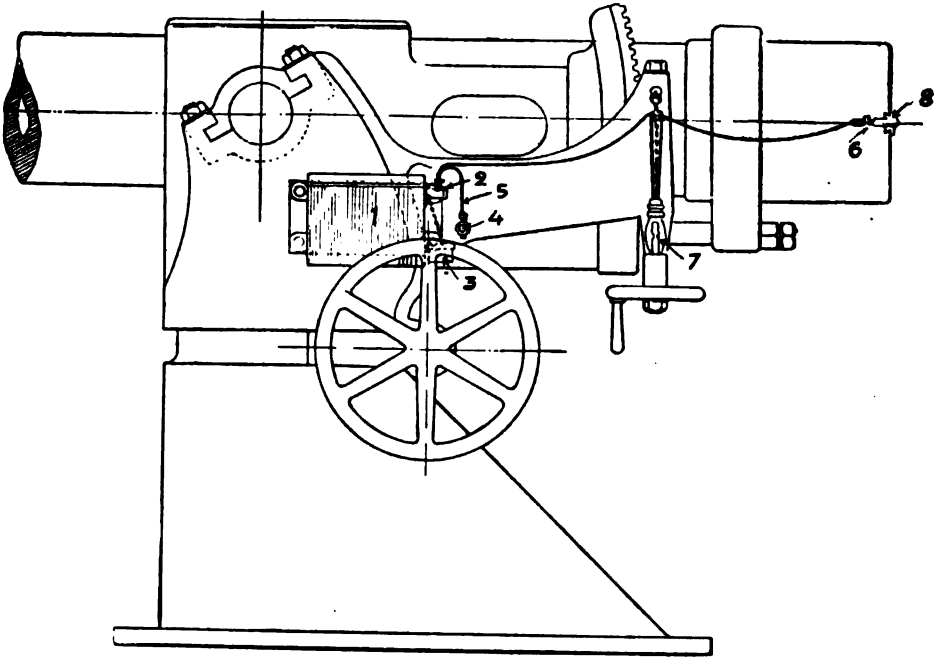
(3) **All primers now being issued for B. L. Rs.** are either electric or percussion (not "combination"), and all locks on B. L. Rs. are combination-, electric-, and percussion-locks.

4. Combination-primers.—All primers for 4-inch, 5-inch, and 6-inch R. F. guns are combination, electric, and percussion, but some locks are combination electric and percussion, while others are interchangeable electric or percussion.

5. In the attachment shown on Plate I, to change to percussion-primers, remove the firing-wire and attachment-lug (8) and replace the latter by a similarly shaped lug containing a trigger to which the lanyard is hooked.

6. The electric-firing attachments shown in Plates II and III are for a 6-inch gun—Vicker's mechanism and automatic lock—and in Plates IV and V, the attachments for a 12-inch turret-gun with Mark VIII lock. The attachment for the latter consists of the insulated firing-wire (1) connected to the lug (2), the firing-

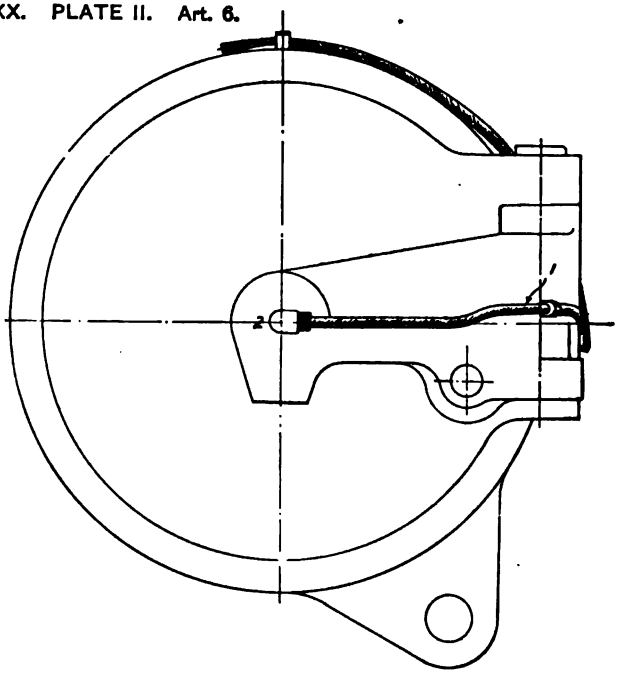
CHAPTER XX. PLATE I. Art. 5.



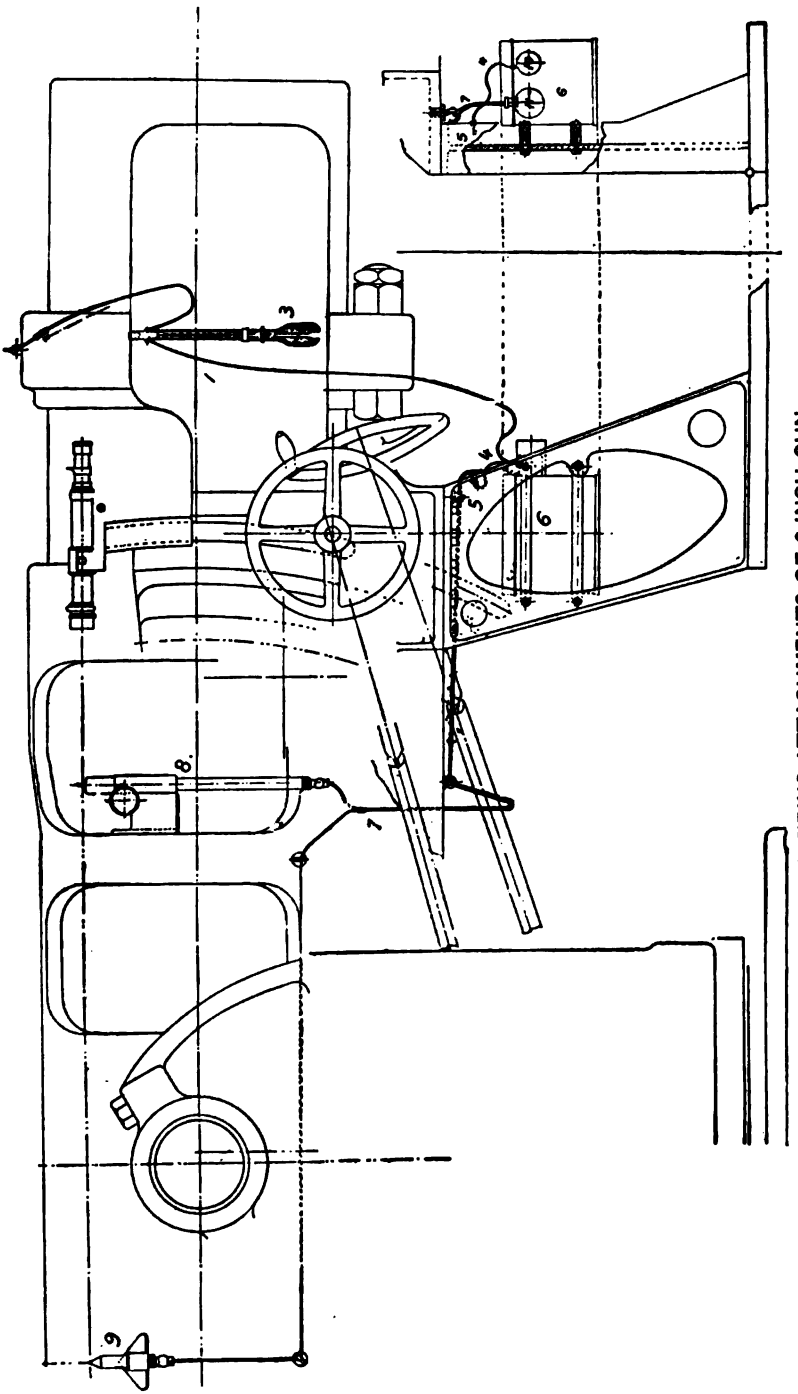
1. Battery-box.
2. Battery terminals.
3. Cover.
4. Earth terminal.
5. Earth connection.
6. Gun terminal.
7. Firing-key.
8. Attachment-lug.

ELECTRIC FIRING-ATTACHMENTS FOR 4-INCH GUN.

CHAPTER XX. PLATE II. Art. 6.



ELECTRIC FIRING-ATTACHMENTS OF 6-INCH GUN



ELECTRIC FIRING-ATTACHMENTS OF 6-INCH GUN.

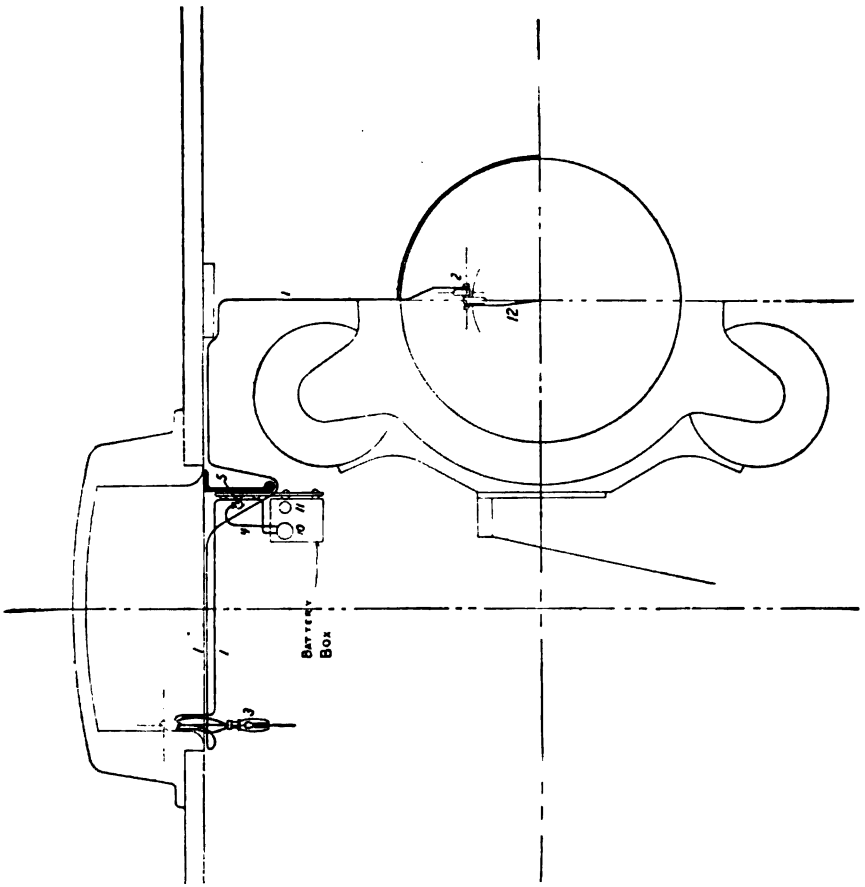
key (3), the battery (6), the earth connection (4), the earth terminal (5), and the battery terminals (10).

7. **The battery** consists of a number of Mesco dry cells connected in series—each cell sealed with pitch; the battery, having an average E. M. F. of 4 or 5 volts, resistance 1 ohm, is put up in a tightly covered "battery-box" which is secured to a training part of the mount or turret. The poles are connected to the battery terminals, which are protected when the circuit is not in use by a watertight cover. The poles are also connected to the terminals (11), from which are led the connecting wires (7) to the night-sights (8) and (9), which are explained in the following chapter.

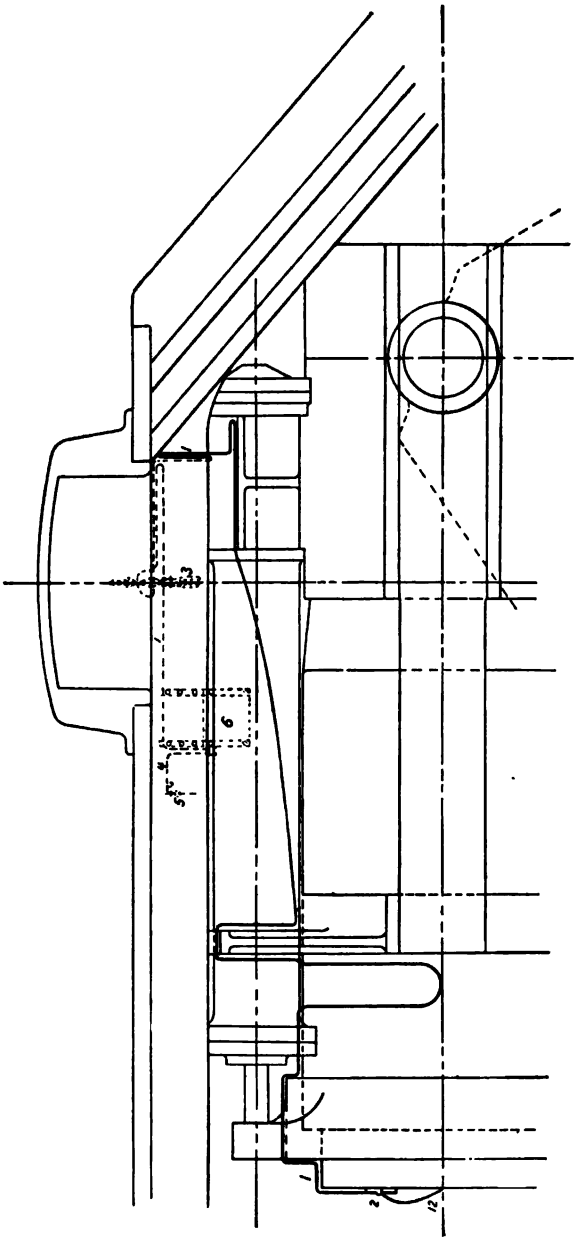
8. *One pole of the battery* is connected to the gun-carriage, or to the turret-framing, by a short wire, with brass cones at each end. This wire is called the *earth-connection* (4), and its ends go respectively to one of the battery terminals (10), and to a socket on the carriage or turret-framing called the *earth-terminal* (5).

9. From the other battery terminal is led the firing-wire (1), in which is inserted the firing-key (3), to the lock (2). The current thus passes from battery through firing-wire and firing-key to the lock and insulated firing-pin which rests against the primer; after passing through and heating up the bridge of the primer, it goes to the grounded part of the primer, thence to gun, mount, earth-terminal, and earth-connection, to the battery again.

10. **The firing-key** (3), for this mark, consists of two pieces of wood, shaped to fit the hand and joined together at the smaller end. Each piece is fitted with a brass contact-stud projecting from its inner face, the natural spring of the wood keeping the two parts separated and so maintaining, normally, a break between the studs. The adjacent ends of the two sections of the firing-wire enter longitudinal holes, bored one in each part, and are secured by screws to the contact-studs. Consequently the break in the firing-wire is closed when a squeeze of the hand brings the contact-pieces together. The other breaks are in the firing mechanism, both in guns of latest and of less recent type. In the rapid-firing guns, the firing-point does not connect with the



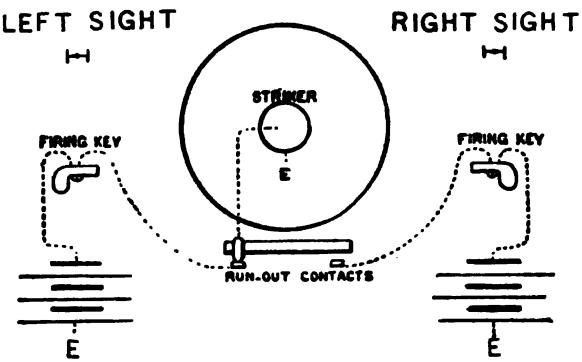
ELECTRIC FIRING-ATTACHMENTS FOR TURRETS.



ELECTRIC FIRING-ATTACHMENTS FOR TURRETS.

primer, nor the contact-point of the firing-case with that of the attachment-lug, until the breech is entirely closed. In B. L. guns, also, the firing-point is automatically pushed against the primer and the connection made only on completion of the fermeture.

11. In turret-guns, as is shown in Plate V, a short wire (12) leads from the contact-lug (2) to the lock, at which the connection is made by closing the wedge of the lock. The contact-points at (2) must touch before the circuit is completed, and this occurs only when the breech is entirely closed. These two "breaks" are considered a sufficient precaution against premature firing,



6-INCH RAPID-FIRE GUN CIRCUITS.

and no accident, of this kind, has occurred with the electric attachments of U. S. naval guns.

12. In the British Navy an additional break, called the "run-out contact," is made in the circuit; the system is shown by the diagram. Two batteries are used, the run-out contact is made only when the gun is in battery and a trigger firing-key instead of bulb is used. The trigger-key with pistol-grip has been adopted for all guns of the U. S. Navy that are fired by electricity. The latest designs are equipped with a pistol firing-key on each side of the gun, either or both of which may be in the firing-circuit.

13. Care of electric-firing attachments.—While the firing batteries should remain unimpaired for several years, it frequently

happens that some of the cells deteriorate from internal action, and consequently it is very necessary to keep a close watch on each battery in order to replace defective cells. For this purpose "battery-testers" are supplied, consisting of a fuse-bridge in circuit with a resistance-coil such that, if the firing-battery is in proper condition, it will illuminate the bridge without burning it out. Firing-batteries should be tested by applying the points of the testers to the battery-terminals, and if the current fails to illuminate the bridge, the battery-box should be opened, the trouble located, and the defective cell or cells replaced by new ones. Of course, if a battery be allowed to short-circuit in any way, such as by connecting the terminals, it will run down; but beyond this no trouble with the batteries is to be anticipated save the occasional deterioration of single cells by local action. Above all it must be remembered that a battery which is in good condition will never give out suddenly—there is no possibility of a battery which tests properly in the morning failing in the afternoon. A battery will fire thousands of primers before it is exhausted and will fire much more rapidly than any gun can be loaded, without showing any material loss in strength. Consequently, if reasonable care is taken to watch the battery, it need never be feared that it is at fault when a missfire occurs—the fault will most certainly be found to be somewhere in the circuit. Moreover, there is a practical certainty that the primer itself will not fail if the normal current is sent through it. Every primer is tested with a current after manufacture, and such an occurrence as an electrical primer, which will not explode with the ordinary current, is rarely found at the naval proving-ground where electric-firing has been used for several years. Besides watching the batteries, then, the most important thing is to see that there is no break in the electric connections and no excessive resistance due to imperfect or dirty contacts. On guns other than those in turrets, the firing-key and wire and the earth-connections should be removed after exercise so as to allow putting the cover over the battery-terminals, thus preventing short-circuiting the battery by water or other means. The terminals of the wires and the contact-studs of the firing-key should be kept clean and free from grease; they should be kept in a dry place.

The electric firing-pins and the attachment-lugs may also be habitually kept off the rapid-fire guns, if thought desirable, except that attachment-lugs which are secured by screws should be kept in place,—to prevent constant wear making the screws too loose. When the lug is kept on the gun its spring-socket can be protected by keeping a soft-wood plug in it.

14. In the case of turret-guns, the connections at the battery-terminals should be broken after exercise and the cover put on, but other portions of the attachments should be kept in place.

Missfires.

15. The daily test having shown that the firing-battery is in good condition—the connections between the cells good and no cell run down—and examination having shown that all contact surfaces are clean and free from grease, it is only necessary, in order to prepare for firing, to seat the terminals of the firing-wire and of the earth-connections firmly in their respective sockets. If, after this, a missfire occurs, it may be considered as almost certainly due to one of the following causes:

(1) *The shock of firing,* or some other cause, may have loosened one of the connections. This is the most frequent cause, and after a missfire no time should be lost in hunting elsewhere for the trouble until it has been determined that the connections are in order. With the attachments in use at present, the first discharge of a heavy gun will often jar the connections loose, no matter how carefully and firmly they are made. A few seconds should suffice to determine this and to remedy it.

(2) *A leaky primer* may have fouled the primer-seat, or may have coated the point of the firing-pin with an insulating residue. If there has been any escape of gas from the vent of a B. L. R. gun, the primer-seat must be well cleaned before entering the next primer, and in case of a leaky primer in a R. F. cartridge-case, the point of the firing-pin should be wiped clean before the next fire.

(3) *Grease or dirt* may have coated some of the contact-points, or even the primer itself. If other cause be not discovered, wipe all the contacts clean with a dry rag.

(4) *In rapid-fire guns the inner point of the firing-pin* may have been struck by something and bent over so as to short-circuit with the breech-plug. If this has happened, it will be seen on opening the breech and can be remedied at once by bending the point back.

(5) *Failure of the primer to light the ignition-charge:* this would be caused by a defective or a displaced ignition-charge; since it does not involve failure of the firing-attachments, this cause really has no place under this heading. The causes are the same as those that produce "hang-fires," which are exceedingly dangerous, because of the difficulty of distinguishing them from *missfires.* It should be borne in mind that if the primer has not exploded, which will usually be known with B. L. guns, there is bound to be a defect in the firing-circuit and there is no danger. If the primer *has* exploded, it may be a *missfire* or it may be a *hang-fire;* the only way of ascertaining is to wait. An advantage of these guns is that other primers may be fired into the same powder-charge, without opening the breech, until the gun fires. With a R. F. gun, it is impossible to tell whether or not the primer has fired and there is nothing to do but to wait; the whole charge is disabled if it develops that it is a missfire.

16. Wear of primer-seat.—In guns of B. L. R. type the greatest pains should be taken to prevent any wear or erosion of the primer-seat, as a very slight enlargement will result in gas-leaks to the rear with possible disablement of the firing-lock and injury to the gun-crew. This will probably make it necessary to keep primer-seats well coated with oil, and consequently one of the important things to do in preparing for firing exercises is to carefully wipe dry and clean the primer-seats. A small pine stick and dry cotton waste will serve for this purpose.

17. Oil in chamber.—In rapid-fire guns the surface of the cartridge-case is so great that it is improbable that any amount of oil in the chamber will insulate the case from the gun. It will be a useful precaution, however, to wipe the face of the breech-block dry before commencing firing.

18. Strength of battery.—Besides measuring the voltage of the battery, preliminary to firing, it is well to test it with the whole circuit connected. The normal voltage is ample for firing

with a circuit which is in good order. But some minor defect frequently adds resistance to the circuit (without actually breaking it), through which a stronger battery could force current enough to fire the primer. Sometimes the ordinary battery will fire the gun if the key is kept pressed down for several seconds. For this reason, the tendency is to use stronger batteries; on some ships, firing-circuits have been improvised by utilizing the ship's bell-circuits, with current from batteries or rotary transformers.

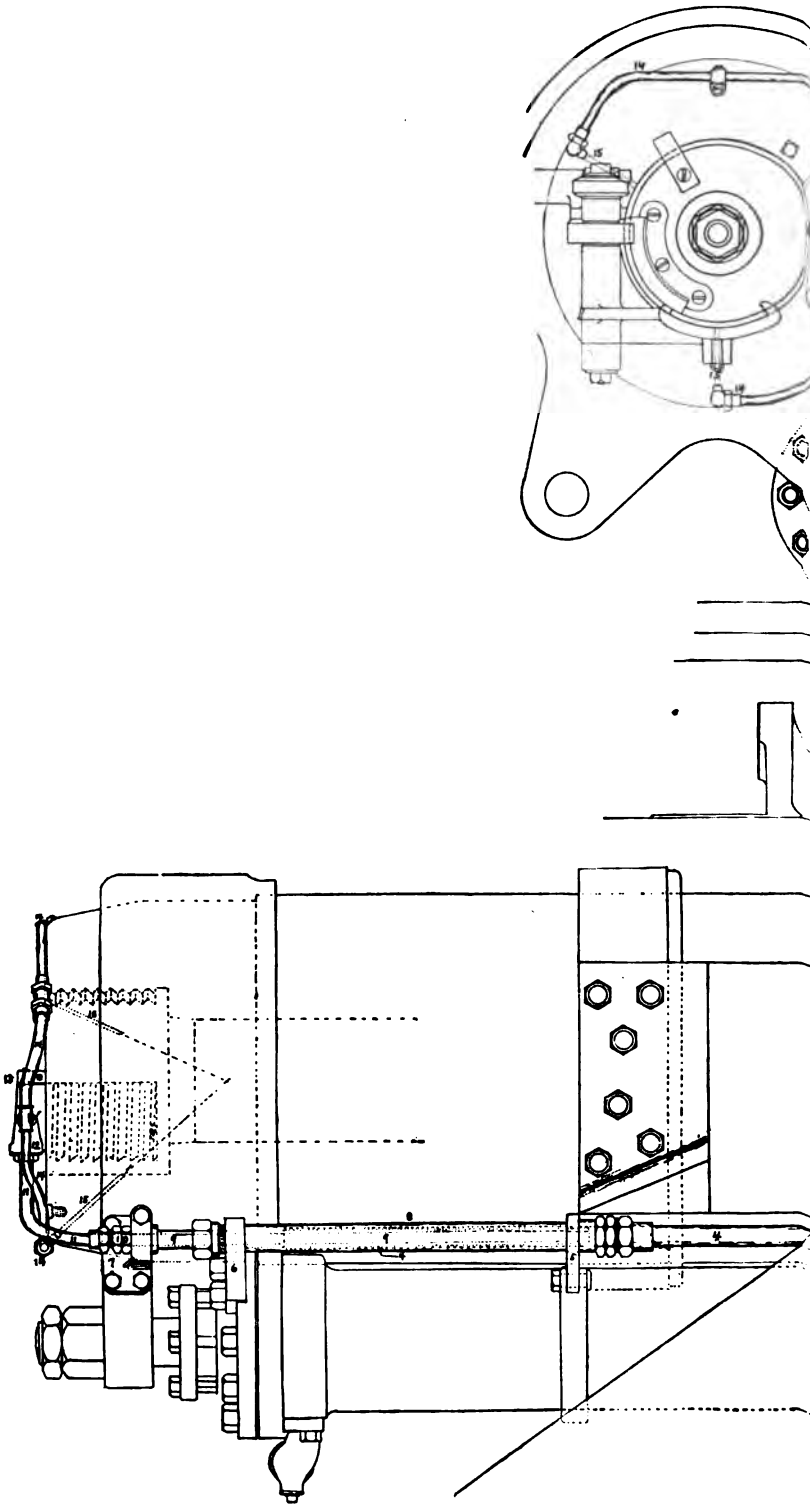
Gas-Ejecting Apparatus.

19. Prior to April 13, 1904, it had been noted, and in a few instances reported, that after firing a smokeless-powder charge in a heavy gun, one of the products of combustion, which remains in the bore, is an inflammable gas which, particularly after sustained firing, is so hot as to be nearly incandescent. In some cases this gas had been known to burst into flame as soon as the breech was opened. It was called a "blow-back" or "flare-back" and the flame was supposed to be of but little intensity. It was also thought that the flare-back would only occur when the gun was firing into a wind of some force. The seriousness of this quality of smokeless powder was realized only after it had caused an explosion in the Missouri's after-turret in April, 1904. A flare-back, occurred during the loading, ignited the half-charge in the chamber and the flame was communicated to the other half-charge on the ammunition-car and to several bags of powder in the handling-room.

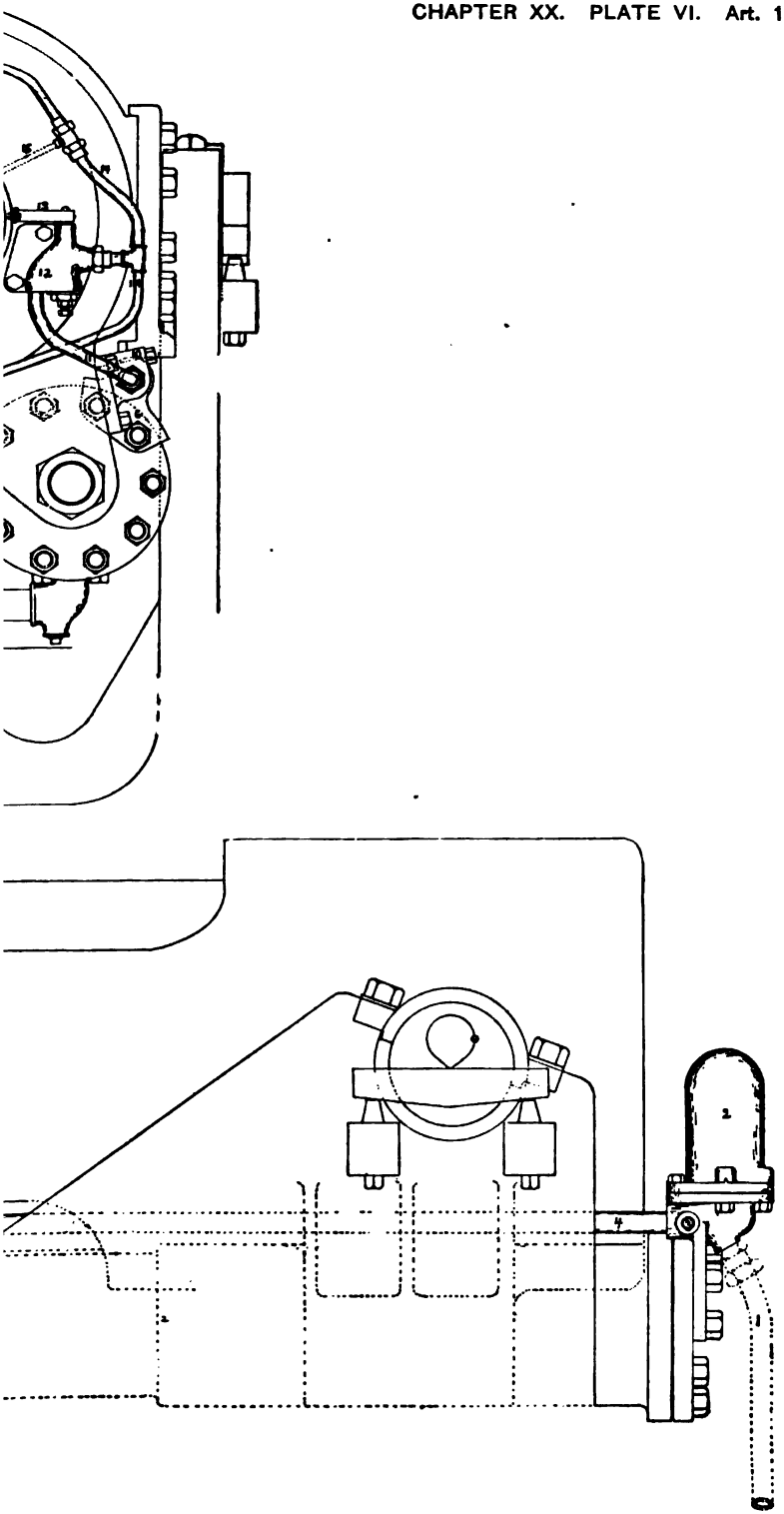
20. It was thus made clear that this inflammable gas must be forced out of B. L. guns after each round. All such guns will be equipped so that the gases in the chamber will be driven out through the muzzle by an air-blast of at least 100 pounds pressure. Many intermediate guns have had air-nozzles and hose attached to their rammers; the air-jet is to be turned on only while ramming the projectile.

21. A gas-ejector, as fitted to the turret-guns of the Kentucky, is illustrated in Plate VI. The drawing shows the left gun of a 13-inch turret.

22. *An air-compressor,* connected to an accumulator, supplies



GAS-EJECTOR FOR 13-INCH



GUNS OF THE KENTUCKY.

the air, at a pressure of about 130 pounds, through the flexible connecting hose (1). The air passes through a check-valve (3) to the stand-pipe (4); the small chamber (2) acts as an accumulator. The stand-pipe (4) is secured to a non-recoiling part of the mount; it remains to transfer the air to a part of the apparatus that is secured to recoiling parts. This is done by a sliding-joint which is similar to the expansion-joints of steam-pipes; there is a stuffing-box at each end; parts of the outer portion (8) of the joint are secured to the recoil-cylinder by the lugs (5) and (6). *The stand-pipe* extends nearly to the rear end of the joint and fits closely around the pipe (9), which is secured to the lug (7), attached to the yoke,—a recoiling part; the length of these sliding surfaces of (4) and (9) is greater than that of the recoil. The pipe (9) connects through a stuffing-box with (11), by which the air is conducted to the valve-chamber (12). From the latter, a two-branched distributing pipe (14) connects with the nozzles (15). These nozzles are three in number and are bored from the face of the breech through to the screw-box at an angle of about 45 degrees; their direction is such that the blast from each meets the others at a point well inside the gas-check seat.

23. *During firing*, the air-pressure is kept turned on and is maintained in all the piping up to the valve-chamber (12). The valve is worked by the lever (13) which is forced rearward, against a spring, during the translation movement of the breech-block. On the inner end of (13) there is a small spring-lug which engages the block only while opening. The breech mechanism is to be operated in the usual manner with no delay by the action of the gas-ejector; the air-blast, although in action only for the very short time that it takes to slide the block to the rear, suffices to clear the bore.

New Method of Cleaning Out the Bore of Guns.*

24. In this apparatus compressed air is blown through the gun from an air-flask or other suitable source of supply of com-

* *This Gas-ejector*, the invention of Lieut. F. S. Sawyer, U. S. Navy, having proven successful on trial, is being installed in many turrets and

pressed air, and this air is admitted before the breech-plug is out of the screw-box, and it is preferably blown into the bore of the gun from a plurality of jets set tangentially to the axis of the bore, so as to give a vortical direction to the air-blast, and this vortical direction preferably follows the rifling, so that the bore may be more effectually cleaned out. In addition to this air-blast just referred to, water in the form of a spray may be admitted, and this spray-apparatus may be operated by turning on the air, as will be hereinafter described.

25. Reference is had to Plates VII and VIII, in which the same parts are indicated by the same letters throughout the several views.

26. Figure 1 is a rear view of the breech of a gun fitted with the well-known Welin breech-plug. Fig. 2 is a section on a larger scale. Fig. 3 shows a modified form of air- and water-pipes. Fig. 4 shows the air-pipe let into the breech of the gun. Fig. 5 shows a modification in which the air is blown into the blanks between the screw-threads. Fig. 6 shows a section, on an enlarged scale, along the line 6 6 of Fig. 5 looking in the direction of the arrows; and Fig. 7 shows a section, on an enlarged scale, along the broken line 7 7 of Fig. 5.

27. *A* represents the body of the gun, which is provided with a suitable screw-box A^0 for the breech-plug *B*. While this breech-plug is of the Welin type, the invention is equally applicable to the ordinary slotted screw-plug or any of the three-motion guns in which there is first a motion to unlock, then a longitudinal mo-

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is likely to be adopted for intermediate guns as it has developed that the smoke of primer and ignition-charge should be blown out to give the loaders a clear view of the chamber in addition to getting rid of the poisonous and inflammable gases. This invention marks a distinct step in safety and rapidity of firing.

Plate VII shows some of Lieut. Sawyer's original drawings. Figs. 1 and 2 show in profile and in section, a turret gun fitted with the device in combination with a water-pipe and nozzles designed to throw a spray of water vapor into the chamber. The water-pipes have not been fitted to guns in service. Fig. 3 shows the water-pipe inside the air-pipe and both are sunk flush with the surface in Fig. 4. In Fig. 1 the nozzles are set tangential to a small circle instead of meeting at a point; this was designed to give a vortical motion to the blast.

tion rearward, and then a swinging motion imparted to the breech-plug in order to open the bore. Moreover, the invention might with slight modifications be adapted for use with Krupp or other type of guns.

28. *C* represents the gas-check, which is shown as of the De Bange type, while *D* represents the mushroom. This gas-check *C* seats on the cylindrical surface a in rear of the slope a' of the powder-chamber and terminates at the edge a^2. (See Fig. 2.)

29. *E* represents an air-pipe which is connected by the feed-pipe *E'* to any suitable source of air-supply. (Not shown.) This pipe *E'* would preferably be connected by any suitable flexible connection at or near the point of the gun where there is least vertical motion—for instance, at or near the trunnions. A flexible hose would form a good connection; but any suitable connection may be used. The pipe *E* is normally cut off from the pipe *E'* by means of the valve E^2, controlled by the valve-stem *F*, having the toe *f*, which toe projects in rear of a suitable trip *G*, pivoted, as at *g*, to the breech-plug when the plug is in the unlocked position.

30. The pipe *E* may be connected by suitable openings *e* to the ducts a^0 (see Figs. 1 and 2) in the breech of the gun, which ducts preferably open into the blanks of the screw-box and are preferably set at such an angle that a line through their axis would clear the angular edge a^2. (See Fig. 2.) Moreover, these ducts a^0 are preferably set tangential to a small imaginary circle (indicated in dotted lines at a^3 in Fig. 1), so that the inrushing air may be given a vortical motion.

31. Compressed air alone may be used to blow out the powder-chamber and bore of the gun, or it may be combined with water-sprays that will now be described.

32. E^3 represents a small air-pipe leading out from the air-pipe *E* and controlled by the valve e^3, which air-pipe opens into the top of the water-tank *I*, which is preferably suspended beneath the gun in any convenient way, or it may be connected thereto by a flexible hose.

33. *H* represents a water-pipe which opens at its lower end into the water-tank *I*, as shown at *H'*. The water-supply may be

cut off, if desired, by means of the valve h'. From this water-pipe H spray-pipes h project into the ducts a^0.

34. In Figs. 1 and 2 are shown the pipe H and spray-pipes h mounted exterior to the pipe E.

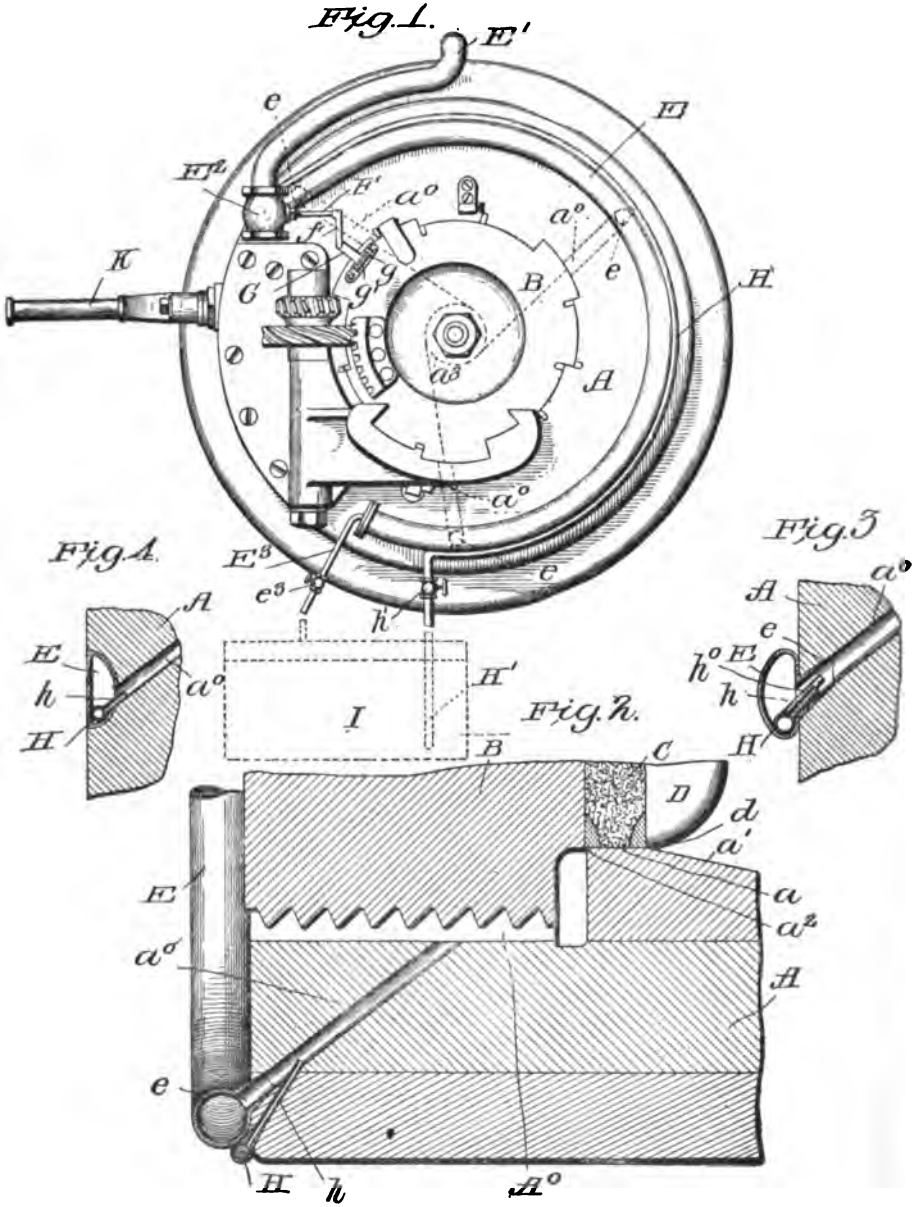
35. In Fig. 3 are shown the pipe E flattened on one side to fit snugly against the breech of the gun, and the water-pipe H is mounted therein, and it is shown as provided with two spray-nozzles h and h^0.

36. In Fig. 4 are shown the pipe E inserted in a recess in the breech of the gun with its rear face flush with the rear face of the gun and with the water-pipe H mounted inside of the air-pipe. This form might be used to apply to guns already built and would not interfere with the mechanism projecting from the breech of the gun. In the form of device shown in Fig. 3 compactness of the parts is secured and very little space is taken up in rear of the gun.

37. The air- and water-pipes may be carried all the way around the gun through three hundred and sixty degrees or only partly around through any desired angle, and the number of ducts a^0 may be increased or decreased at will.

38. In the form of device shown in Figs. 5 and 6 the air-jets e' lead from the pipe E into the blanks of the gun between the screw-threads. No water-sprays are shown in these figures; but these sprays may be added, if desired.

39. (1) **The operation of the device** is as follows: Suppose the breech closed and the plug in the locked position and suppose also it be desired to use compressed air only without the water-spray, in which case the valve h' should be closed and the valve e^3 should preferably be closed. The first motion of the breech mechanism (which, being of the well-known type operated by the hand-crank K, is not described) will cause the breech-plug to rotate through a small angle to the left to the unlocked position shown in Fig. 1. This will cause the trip G to pass in front of the toe f, as indicated in dotted lines at g^0 in Fig. 7. Now the further motion of the hand-crank K will move the breech-plug rearward until the trip G will strike the toe f, rocking the valve-stem F and opening the valve E^2. The trip G is so arranged relative to the toe f that the valve will open just as



GAS EJECTOR WITH WATER-NOZZLES.

(As first proposed by Lieut. F. L. Sawyer, U. S. Navy.)

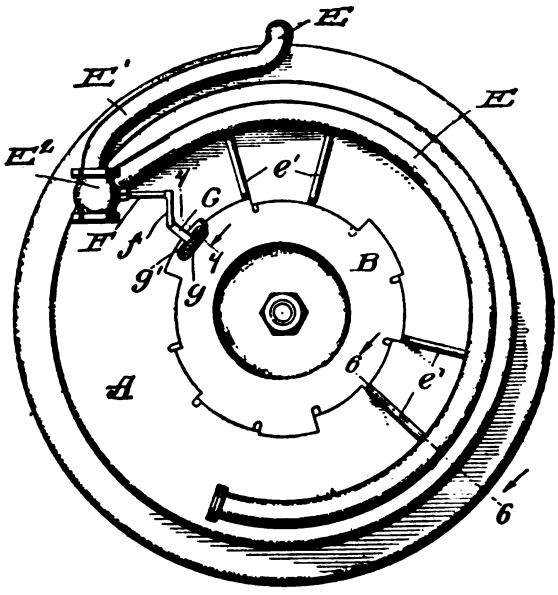


Fig. 6.

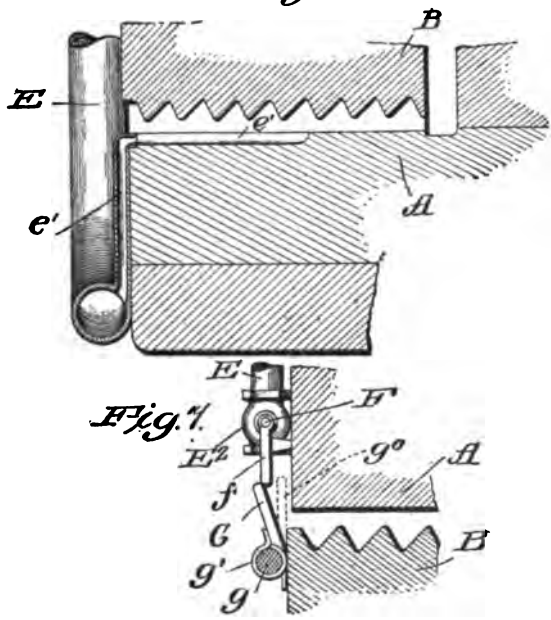


Fig. 7.

NEW METHOD FOR CLEANING OUT THE BORE OF GUNS.

the edge d of the mushroom clears the edge a^2 of the gun, and air will be blown through all the ducts a^0 or e' into the powder-chamber and will be pressed forward in the bore of the gun in a vortical direction following the rifling. This air will carry along with it any gases, cinders, unburned powder, or other loose matter in the bore of the gun and will deliver the same out through the muzzle.

(2) In closing the breech it will be seen that the trip G will strike the toe f, as indicated in Fig. 7, tipping the trip back against the action of the coil-spring g' on the pivot g until the rotation of the breech-plug allows the trip G to pass clear of the toe f, when the spring g' will restore the trip G to the initial position (shown at g^0).

(3) If it be desired to combine the water-spray with the air-jets, the valves h' and e^3 should be opened, the valve E^2 being closed and the parts being in the position indicated in Fig. 1. Now the first motion of unlocking the breech will turn the trip G in the position to engage the toe f when the breech-plug is moved rearward a sufficient distance. As soon as the valve E^2 is opened, the air from the pipe E' will rush into the duct a^0, as already described. A small part of the air will pass through the pipe E^3 and pass the valve e^3 and will enter the top of the water-tank I and pressing on the water will force the latter up into the pipe H' and past the valve h' into the pipe H, from which it will escape by the spray-pipes h. The air-blast through the inlets a^0 will act as an atomizer, separating the water into a fine spray, which will be carried along with the air and will spray out the gun.

(4) It will be seen that when the air alone is used it will expand after leaving the pipe E and will become cool, thus in a measure chilling the bore of the gun, while this cooling effect will be further increased when the water-spray is combined with the air-jets.

(5) After the breech has been opened sufficiently for the gun servant to determine whether the bore is clear the valve E^2 may be closed by hand or in any suitable way.

(6) It will also be evident that the trip G and toe f may be omitted and that the valve E^2 may be operated entirely by hand, if desired.

CHAPTER XXI.

SIGHTS.

Definitions and General Principles.

1. In designing a gun with its mounting, the requirements necessary to attain its two main objects must be kept in view:

(1) After loading as rapidly as possible, to propel the projectiles successively along paths of the same curvature and to absorb the recoil without unduly straining any part.

(2) To rapidly point the gun so as to impart an initial direction to the flight of the projectiles which will cause them to strike the target.

2. The gun, including the breech mechanism and the recoil mechanism, have to do mainly with the requirements in (1); the sights and the training and elevating gears with those in (2).

3. There are two methods of laying guns—directing them so as to strike the target:—*direct* and *indirect* pointing.

(1) *Direct pointing* is employed in firing with high-powered guns when the target is in view from the gun emplacement; it is obviously the method generally used with guns afloat, and the only one in which naval men are seriously interested.

(2) *Indirect pointing* is resorted to when the target cannot be seen from the gun; as in mortar firing from deep emplacements (the usual condition), and in field operations when the fire of a gun is to be directed at an enemy concealed by an eminence not in his immediate front.

4. In one system, the elevation is obtained by laying the gun at an angle above the horizontal which will give the required range. This angle is measured by a "gunner's quadrant," an instrument adjusted to a machined surface on the gun which is parallel to the bore. The quadrant has a graduated arc of 90 degrees, along which one end of the limb travels and is clamped at the angle of elevation required; the limb, bearing a spirit level,

is pivoted at the center of the quadrant. In pointing, the quadrant is set at the proper angle (measured or estimated), laid on the gun, and the latter is elevated until the limb of the quadrant is level; the instrument is removed before firing.

5. For guns of position giving indirect fire, such as coast-defense mortars, the mount is accurately leveled and the elevations may be read from a scale, on the elevating arc, graduated in degrees. Associated with such defenses, is a system of position-finding, designed to measure the angular distance of the target from a fixed vertical reference-plane; the guns are pointed laterally by training them through the same arc, measured on the graduated training-circle, the zero point of which is, with the center of the mounting, in the reference-plane. This method is only applicable to fixed guns on shore.

6. When the target is visible from some point sufficiently near to communicate with the gun, an auxiliary mark, which is visible from the gun, is set up and the sights, set at an estimated elevation, are directed at it. An observer notes the fall of the projectile and alters the position of the mark and the setting of the sights until the target is hit. The latter method is the practical one for naval forces operating on shore; with any system of indirect pointing, an observer, who can see the fall of the shot and thus correct errors in the pointing, is essential.

7. Definitions.—(1) *The trajectory* is the curve described by the projectile in passing from the muzzle of the gun to the point of impact; its vertical curvature is due to the force of gravity. In most cases there is also a slight lateral curvature caused by the rapid rotation of the projectile on its axis; this deviation from the vertical plane of fire, called the *drift,* is to the right for right-handed rifling, and may be partially corrected by a permanent shop adjustment of the sight.

(2) *The axis of the bore* is its geometrical axis; the axis of the trunnions, which, in firing, is supposed to be horizontal, is their common geometrical axis; it is at right angles to the axis of the bore.

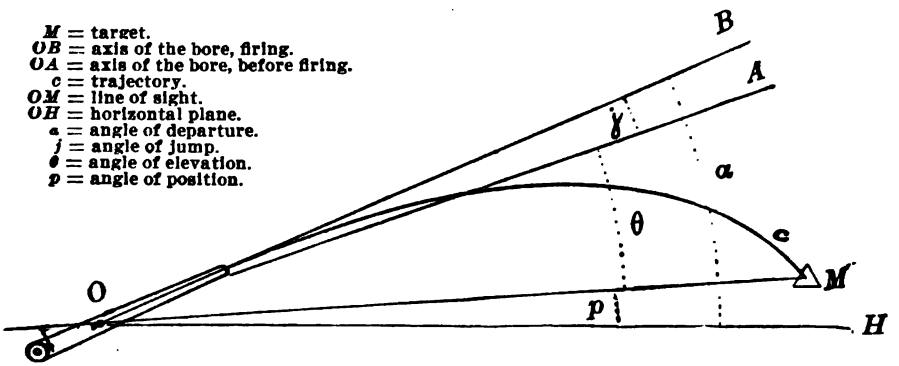
(3) *The line of sight* is a straight line through the two sight points which, in the act of firing, also includes the target.

(4) *The line of departure* is the line in which the projectile is

moving as it leaves the gun, or is a tangent to the trajectory at that point.

(5) *The jump* is the small vertical angle, usually upward, which the axis of the bore describes in the act of firing; it is due to the straining of the mount. It is determined experimentally and is applied as an index correction in marking the sights.

(6) *The angle of position* is the angle included between a line passing through the gun and target and the horizontal plane; for all practical purposes, this angle disappears when gun and target are afloat.



(7) *The angle of elevation* is the vertical angle between the line of sight and the axis of the bore.

(8) *The angle of departure* is that included between the line of departure and the horizontal plane; it is the algebraical sum of the angles of elevation, jump, and position.

(9) *The range* is the linear distance from the gun to the intersection of the trajectory with the line of sight.

8. In pointing a gun, two distinct steps must be taken:—

(1) Adjusting the line of sight to make such vertical and horizontal angles with the axis of the bore that the trajectory will intersect it at a distance from the gun equal to the distance of the target, i. e., setting the sight.

(2) Directing the line of sight at the target and retaining it there until the moment of firing, which is *pointing*.

9. The first step is the duty of the officer in control of the fire, through his subordinates, and requires experience, keen observation, and a high order of intelligence and knowledge of the theory of gunnery. The second step is in the province of the gun-pointer and requires no thought or knowledge of the principles of ordnance or gunnery, being merely a matter of eyesight, nerve, and manual dexterity.

10. The "point-blank" range of a gun is the distance through which its trajectory may—without appreciable error—be assumed to be a straight line; in firing at targets inside such range, the gun is not elevated and the line of sight (disregarding the jump) coincides with the axis of the bore; this distance is necessarily short, but increases as the trajectory is flattened, which is a direct result and one of the great advantages of increasing the velocity. In this case the sight is kept at zero, and accuracy of fire depends entirely upon the gun-pointer.

11. If the target is beyond the limit of point-blank range, which is the general case, some or all of the following adjustments must be made to give the line of sight the necessary horizontal and vertical angles with the axis of the bore: *Jump, drift, range, wind, motion of gun, and motion of target.* The first two are permanent adjustments and their values are determined in ranging the gun. (In this consideration, the errors of the gun itself, variation in the powder, etc., and errors in measuring the range of the target are not touched upon.)

12. When a gun is "ranged" at the proving-ground, a curve of the range under standard conditions for all angles of elevation up to 15 degrees is obtained; the deviations due to drift are also recorded and plotted, and the curve so obtained was formerly assumed a straight line without much error. In the latest sights, the exact value at all ranges is laid off on the azimuth scale and the compensation is accurate. During the ranging, the gun is directed at a mark on a paper screen, at a known distance from the gun, by means of bore-sights; the projectile makes a round hole in the screen, the center of which gives the offset, due to *jump,* from the point aimed at.

13. The jump depends somewhat on the rigidity of the gun-platform and is variable, but its value is only a few minutes of arc.

14. Fitting and marking sights.—These data obtained, the gun is returned to the gun factory to have its sights fitted. By means of T-squares secured to breech and muzzle tompions, and a trunnion square, a line parallel to the axis of the bore is obtained which passes through the front-sight point—if open-sights are being fitted. The distance between the sights— the *sight radius*—being known, the right triangle is solved to fix the heights of the rear-sight point above this line for the different angles of elevation; after applying the jump, the ranges corresponding to these angles of elevation and heights of sight-bar are taken off the range curve and marked on the sight-bar. The ranges are marked in small increments, usually 100 yards, on a part of the sight which is in plain view. Each sight also shows for what weight of projectile and muzzle velocity it is graduated. Whenever practicable, the elevations and times of flight for the different ranges are also marked on the sight; the time of flight being thus made easy to obtain, when setting time-fuses. The elevation in degrees is sometimes marked on the elevating-arc as well.

15. To compensate for drift, the plane in which the line of sight is revolved while raising the sight, is, in most sights now in service, inclined to the left by an angle of from one to three degrees to the vertical plane through the axis of the bore. This method over-compensates for short ranges and under-compensates at long ranges; the correction by the azimuth scale is preferable.

16. Fire-control.—The above mentioned preparations are in the province of the designer; it remains for the officer in control of the fire, when beyond point-blank range, to direct the proper setting of the sight, horizontally and vertically, so that the projectile will hit the target if the line of sight is accurately directed by the gun-pointer. In setting the sights, the range, effect of the wind and of the motion of the gun and target are to be considered.

17. Errors in firing.—Of the errors that occur in firing, the vertical ones are the more serious. The target—the enemy's ship—has its least dimension in this direction; it is long enough to be hit by a comparatively wild shot, but it is often of little height. Mistakes in measuring the range cause only vertical errors. Since it is very difficult to tell how much too high or too low a shot goes by noting its point of fall in the water, it is harder

to correct vertical errors; and finally, the motion of the gun is more rapid and irregular in the vertical plane, hence vertical errors in *pointing*, as well as in *sight-setting*, are also the more frequent.

18. The effect of the wind is not comparatively great except when strong winds act on the light projectiles of the secondary battery; its force can only be estimated, and its effect depends also on its direction; when at right angles to the trajectory it will cause only lateral deviations. Experience alone, coupled with good judgment, is of practical value in compensating for the wind effect; however, it is responsible for only minor errors, when compared with those due to other causes.

19. The motion of the gun is known in speed and direction, while that of the target may only be estimated; the two may tend to neutralize each other, or they may combine to cause an enormous lateral or vertical error, or both. Here again, experience and judgment alone are of practical value.

20. The importance of fire-control.—Fire-control, of which sight-setting is a part, constitutes a problem so intricate and extensive that it should be treated as a science in itself. The combined effects of these separate causes having been determined as far as possible, the vertical component is applied to the range and the sight is set to correspond; the lateral component is applied to the line of sight as well, with the result of swinging it through a small horizontal angle. The sight being correctly set, use is now to be made of the skill of the gun-pointer.

21. Historical.—Until 1801, nearly 500 years after the introduction of cannon, no sights of any kind were used in pointing guns; up to that time the men were instructed to look along the "line of metal," or exterior of the gun, and aim at some point of the enemy's ship above that to be hit. When first introduced, both front and rear sights were fixed and merely gave a line parallel to the axis of the bore; this innovation was strongly objected to by many prominent naval officers, Lord Nelson among them. It was not until much later that a French army officer succeeded in introducing movable rear-sights graduated to cable lengths. Until the beginning of the last century it would perhaps have been superfluous to have introduced accurate sighting meth-

ods when the gun element had contributed so little to accuracy. The guns were smooth-bored and were single-shotted, double-shotted, or loaded to the muzzle with grape, with little thought of the effect on the trajectory. Then, too, the powder-charge was roughly measured out, and if it was thought that the powder had deteriorated, a quart or more was thrown in. Under such conditions, the gun had to be very close to the enemy to have a reasonable chance of hitting him; fleet actions were melees and single ships sometimes decided the issue only after hours of fighting while lashed alongside each other. The British generally won in these "yard-arm to yard-arm" affairs, and other great navies tried to follow the fashion set by them; it was even hinted that fighting at long range, even if skillfully done, was cowardly. Under the circumstances, the execution done by the guns of the day was quite sufficient, and pieces of greater accuracy were neither needed nor often considered.

22. Sights in general.—The old conditions of short-range fighting exist no longer, and the torpedo alone will probably compel the decisive parts of future actions to be fought at ranges greater than 2000 yards. The gun has so improved in accuracy that the sight is now to blame for most of the errors due to defective matériel. The greatest errors of all, supposing the sight to have been set with reasonable accuracy, are due to the difficulty in pointing the line of sight at the target and then holding it there long enough to fire the gun. There are numberless patents on devices for overcoming the *visual difficulty* in this operation, but, for our purposes, they may be divided into three classes, viz.: the ordinary *open*-sight; the *peep*-sight; the *telescope*-sight.

Open-Sights.

23. The common "bar" sight (see Fig. 1), with notched rear sight and a more or less cumbersome front-sight point, is the oldest form known and is still the one most widely used. The aim is obtained by bringing the bottom of the notch, tip of the front sight, and target in line. In the naval service, it is used on all small-arms and on many secondary-battery guns, as well as the modification of it employed as an auxiliary sight for many main-

battery guns. The sight shown by Fig. 1, called the Parkhurst sight, is the one still in general use on Hotchkiss R. F. guns. The front-sight mass, bearing a roughened point, is screwed to the locking-ring of the gun. The bar is held in and guided by a deep groove cut in the right side of the face of the breech; when raised, it is clamped by a milled head. The sight-bar is inclined to the left at a small permanent angle—depending on the size of the gun—as a drift compensation; thus the drift, increasing with the range, is roughly corrected by the motion of the rear-sight notch to the left—given it by raising the bar—which correction also in-

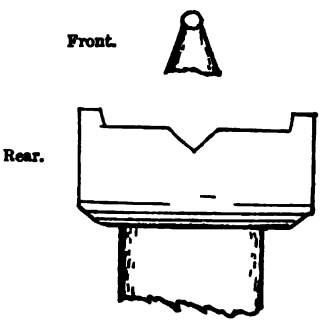


FIG. 1. ART. 23.

COMMON BAR-SIGHT.

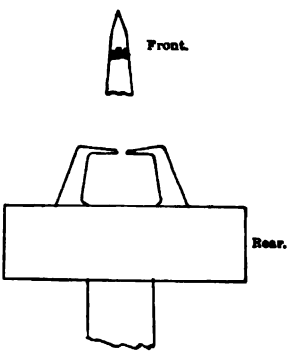


FIG. 2. ART. 24

LYMAN SIGHT.

creases with the range. With this sight, no lateral correction can be applied to the line of sight to compensate for deflections caused by the wind, speed of target, etc., and errors can only be corrected by directing the line of sight to one side of the mark. A disadvantage of this particular form of the open-sight is that the target is too much concealed by it, particularly when it is below the line of sight; when the gun is depressed to bring the mark into view, it suddenly appears above the front-sight and the gun must be elevated again. For this reason the form shown diagrammatically in Fig. 1 is, theoretically at least, the least satisfactory form of the open-sight.

24. The Lyman sight.—The open-sight shown in Fig. 2, a form of the Lyman sight, was, before the adoption of the telescope-sight, largely used on main battery guns. In aiming, the tip of

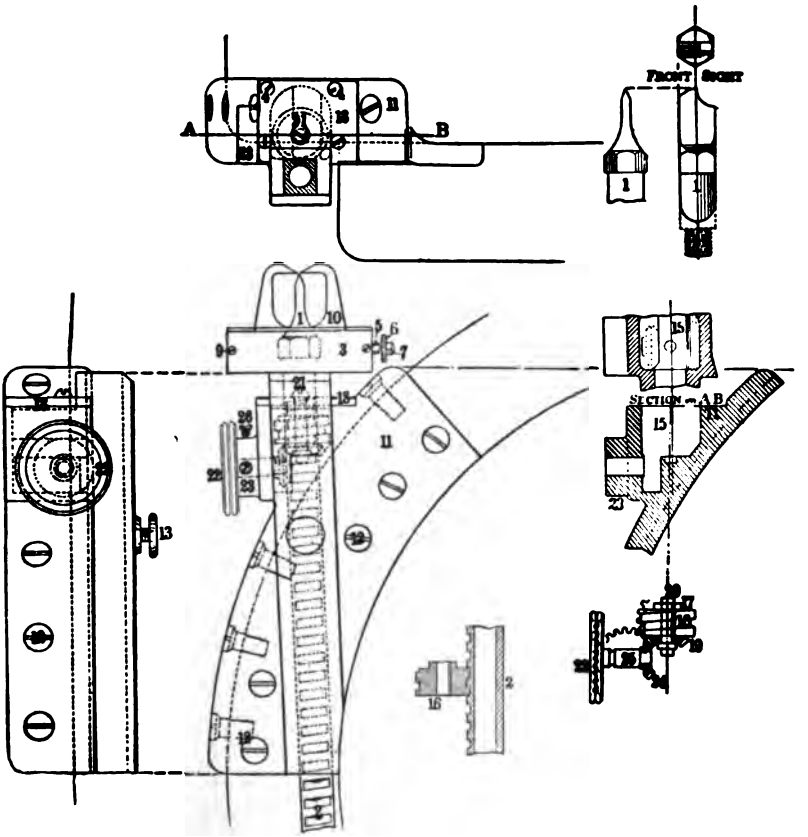


FIG. 3. ART. 24.

SIGHTS AND SIGHT-BOX FOR OLD STYLE 8-INCH B. L. R.

the front-sight is seen midway between, and on a line with, the two rear-sight points; the sights then are less likely to obscure the target when it is below or to one side of the line of sight. To this end the front-sight should be as slender as practicable. A

sight of this kind is shown by Fig. 3; the front-sight (1) is secured to the gun near the trunnion. The rear sight-bar (2) rests in a box (11) screwed to the breech of the gun, and is raised and lowered by the hand-wheel (22), through pinion and worm gearing designed to prevent the sight from jarring down. The sight-box is inclined to the left to compensate for drift. The rear-sight (10) is mounted on the "sliding leaf" (3) by which it is given lateral movement in the horizontal plane by a threaded shaft which runs through it and is turned by the milled head (6). This device makes lateral adjustment of the line of sight possible and

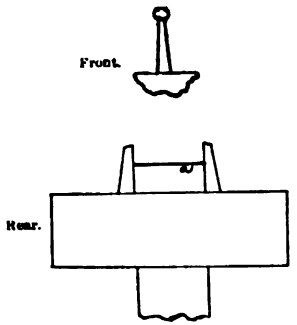


FIG. 4. ART. 25.

lateral deflections from any cause may be corrected. The rule in moving the sliding leaf to correct the deviation noted by the fall of the preceding shot, is to "*move the leaf in the direction you wish the shot to go*" in order to bring it on the target. To set it for the first shot, move the leaf *against* the motion of the gun, *against* the wind, or *with* the motion of the target.

25. The "H" sight, shown in Fig. 4, is a form of the open-sight used on the Maxim-Nordenfelt automatic and semi-automatic guns and on some of the British-built guns of other classes. In pointing, the front-sight point is seen at the middle of the wire (*a*) which is stretched between the uprights of the rear-sight; the latter is secured to a sliding leaf. The graduations of the scale on the leaf of the various sights are not uniform, and it may be found that the divisions represent millimeters, minutes of arc, or

knots of speed of gun or target at a distance of 2500 yards, with motion perpendicular to the line of fire, etc. However, this is not a great drawback, since an officer who knows the graduations will order the sights set at so many divisions to the right or left, after estimating the compensation required, and a subsequent correction will be by comparison. As has been indicated, horizontal errors are least troublesome, but combinations of them that will produce a large total error are liable to occur, and it is important to be able to correct them even if small. To this end, all sights are fitted, or will be modified, to permit the lateral adjustment of the line of sight; when the above is not the case, the only method is to aim to one side of the target. The " H " rear-sight gives a good view of the target, and for this reason the front-sight *should be* long and slender; some of those now fitted are very low cones of large diameter.

26. Inherent defects of open-sights.—Many of the open-sights in the service are secured to the gun or a recoiling part of the mount, and, obviously, the gun-pointer's eye cannot be placed very near the rear-sight. In using the ordinary notched open-sight and, to a greater or less degree, all of its modifications—only two of which have been touched upon—the following visual difficulties in correct pointing present themselves:

(1) The eye must clearly see three objects in their true shapes at the same instant: rear-sight, front-sight, and target, all at different distances. While the eye will readily focus itself at any distance, it is impossible for it to adjust itself for even two objects, one of which is a few inches distant and the other hundreds of yards away; if any one of the three is seen clearly, the others will at best appear only as blurred outlines.

(2) The two sights must be seen as points, and the same portions of them must be aligned on the target irrespective of changes in the intensity or direction of the source of light. The sights have certain dimensions, and even if their central portions can be seen as points, they will appear to move vertically as the intensity of light changes, and laterally as its direction varies.

(3) The eye must be held accurately in the line of sight and, to obtain the best results, it should always be at the same distance from the rear-sight. The latter condition can be fulfilled, but it

is an inconvenience to have to do it. While the body may be able to hold the eye in the line of sight for a short interval, it is exceedingly difficult under conditions found at sea.

27. In the face of these disadvantages, a man with good vision is able to make a compromise effort to see the three objects at the same time and to align them more or less accurately. A considerable visual error is bound to occur; it is made up of two parts, one showing itself in a displacement of the mean visual line from the true line of sight, the other in a dispersion of successive visual lines under equal conditions. The second may be reduced by practice, as is shown in "aiming drill." The first is natural to each man and probably cannot be corrected; moreover, its amount varies extensively under different conditions of light, etc. For those who obtain good results, it is largely a matter of knack—which many can never acquire; for those who do it, it is at the expense of long practice—mere eye exercise—coupled with such peculiar natural qualities that it has well been said that a good shot, like a poet, is born and not made. Everyone who enters the naval service can, and is required to, attain a measure of proficiency in the art, but for the extreme accuracy desired in heavy-gun-pointing, we should be sure that the angle between the line of sight and the axis of the bore is exactly what the sight calls for, and not dependent on the personality of the pointer; there are enough causes of error without this one.

28. Recent improvements in sights, which amount to a revolution, make it so easy to see and direct the true line of sight on the target that *visual* difficulties are largely eliminated, and any one with fair eyesight can do it. The day of the rare "crack shot" is about over—at least as concerns heavy guns.

Peep-Sights.

29. The "peep" sight was invented for use on rifles, and has given good results. It has various forms, one of the simple ones being shown diagrammatically in the figure. The rear-sight is a blackened disk, concave to the rear, with a very small peep-hole in its center; the front-sight is a small bead on an upright support which must be of the least possible diameter. In aiming, the eye

is held close to the rear-sight, and the target and front-sight are seen in line through the peep-hole. Thus, whenever the target can be seen through the hole it is insured that eye and rear-sight are in line, and it remains only to bring the bead on the same line. Hence two objects instead of three must be seen at a time. Of course, this cannot be done; one of them is bound to be blurred, but it is more nearly possible than in the case of the open-sight, and the visual difficulties are less.

30. The Driggs sights, fitted to Driggs-Schroeder guns, were the first peep-sights used by the navy (see Fig. 6.) The peep-hole is formed by double cross-wires and the front-sight by the

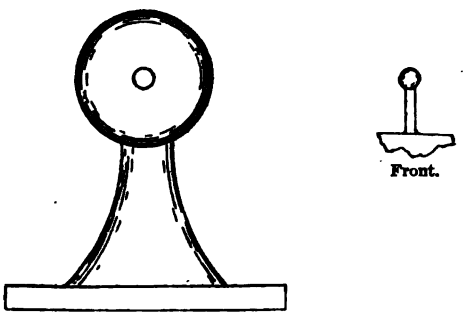


FIG. 5. ART. 29.

TYPICAL PEEP-SIGHT.

intersection of single wires. The front-sight is screwed to the locking-ring of the gun. The rear-sight is mounted on a sliding leaf; its bar works in a sight-box on the face of the breech of the gun; drift is compensated for by inclining the bar to the left. The bar is raised and lowered by a rack-and-pinion device arranged to prevent the bar from jarring down; the hand-wheel has to be pulled to the right before it can be turned backward. Since this sight, as at present fitted, is attached to a recoiling part, the eye cannot be brought close to the rear-sight and must attempt to focus its wires as well as the front-sight and target. For this reason its use has so far resulted in no improvement over ordinary open-sights, though its natural advantages are considerable.

31. In a few instances, peep-sights have been improvised on board ship with good results.

32. Peep-sights are to be fitted in the future as *night-sights* and auxiliary day-sights.

The Telescope-Sight.

33. As long as sights were fitted directly to the gun, the recoil forced the use of the ordinary "bar" sights. When the principle of placing sights on a non-recoiling part of the mount

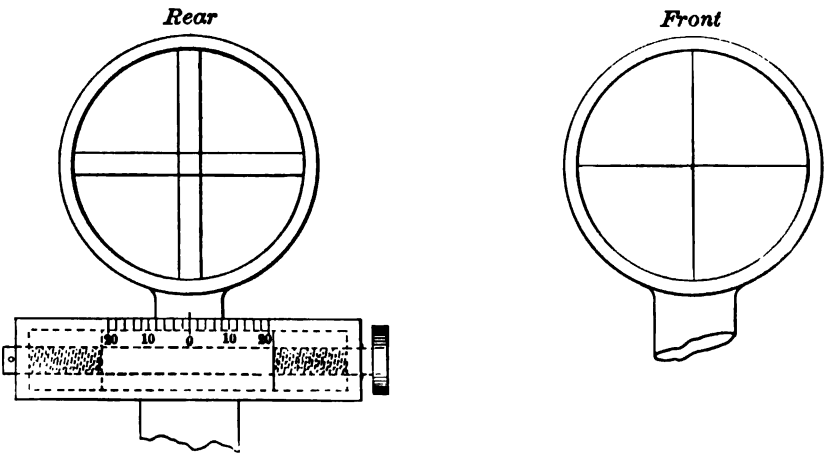


FIG. 6. ART. 30.

DRIGGS SIGHT.

was adopted, making it possible to hold the eye close to the sight, it would have been advantageous to change to peep-sights. But it was the introduction of the telescope-sight, with its great added advantages, that has well-nigh caused a revolution in naval gunnery. It was an improvement so great that it may well be ranked with such as the change from smooth-bore to rifled guns. The United States Navy has led in the general adoption and improvement of this sight and now possesses it in more general use than does any other navy.

34. The telescope-sight was introduced into the British army as long ago as 1857 by Captain Younghusband, and came into extensive use in 1875. Major Scott was then its sponsor, and his device, which is still in use on some guns, provided for removing the telescope after the gun was laid and before firing.

35. Commander Fiske's sights.—In 1890, Lieutenant (now Commander) Fiske, U. S. N., obtained a patent on a telescope-sight which secured to the gun-shield of a gravity-return gun-mount; because of the nature of the mount it was not practicable to so connect the sight that it could partake of the gun's motion. Following the patent of 1890, Lieut. Fiske obtained four patents between 1891 and 1895 in which he provided for attaching the telescope to the gun-sleeve and for making compensation for drift and speed; the practicability of using this form of sight for naval guns was proven by Lieut. Fiske in official tests at sea during 1892, 1893, and 1894. As usual, the innovation encountered much opposition, but the idea was adopted by the Bureau of Ordnance in 1896, with some changes in detail, and has been steadily adhered to, in spite of much skepticism that endured until a very few years ago. The original designs of Lieut. Fiske have been shown to be sound in principle, and he is the pioneer in adapting telescopes to sighting naval guns.

36. The introduction of mounts in which the gun recoils in a sleeve in the line of fire removed the difficulties which had hitherto defeated all attempts to point a ship's guns by means of telescopes. This permits mounting the sight to all intents and purposes on the gun itself, which can be elevated and depressed without disturbing the setting of the sight, yet the latter partakes of all the movements of the gun except recoil, and the eye need not be removed from the sight while firing; indeed, under some circumstances, the pointer can watch the flight of the projectile through the telescope.

37. The telescope retains and adds to the good qualities of the peep-sight; the eye is applied to a small hole in the same way, but, instead of having to focus the target and front-sight, it sees the image of the target and the cross-wires, in the same plane at the focus of the eye-piece lens; the latter, in itself, contributes to accuracy in the proportion of its magnifying power.

The optical axis of the telescope is then *the line of sight* and is so unmistakably defined and easy to see that all visual errors, formerly so fatal to accuracy, disappear. "Nerve and judgment are the only requisites to-day, and any man possessing them can become an expert gun-pointer, if he has ordinarily good eyes." *

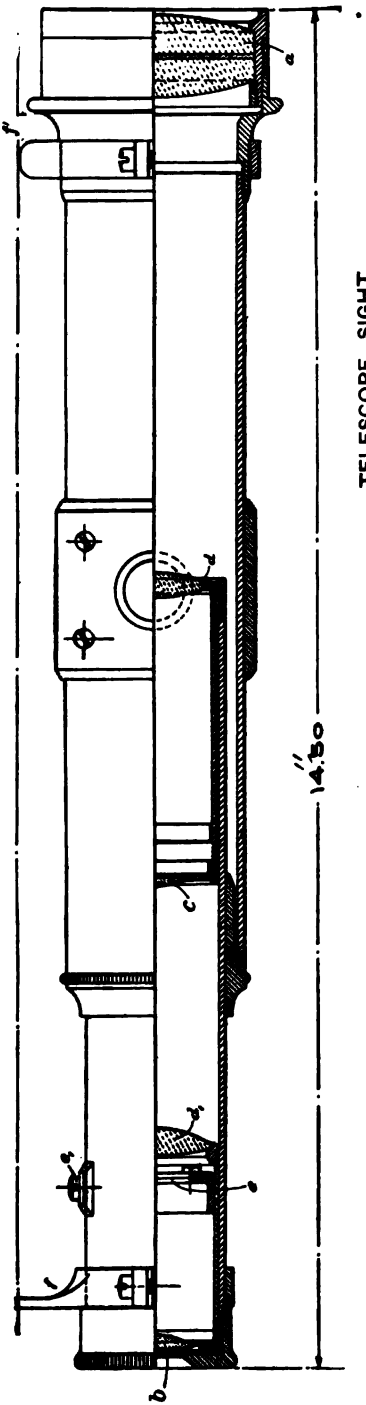
38. First forms of telescope-sights.—Telescope-sights began to be generally used for main-battery guns about 1895 and since then have been steadily growing in favor, until now the tendency is to fit them to secondary-battery guns as well. The telescope as at first adopted (see Plate I) is of the ordinary terrestrial type, fitted with cross-wires; it has an erecting eye-piece which adds two lenses, with a consequent loss of light, and increases the length; but it is highly necessary that the gun-pointer shall not be confused by working with an inverted image of the target. The object-glass (a), the eye-piece proper (b) and (d), the erecting lens (d), and the amplifying lens (c)—placed to increase the field—are firmly secured in place and no focusing for distance is necessary. The object-glass is large, about two inches in diameter, to admit as much light as possible. The magnifying power is 2.5 and the field 17 degrees; this should be large enough to keep the target in the field throughout the roll of any ship, if the pointer is at all experienced.

39. The power of a telescope can be increased only at the expense of reducing its field. The cross-wires are at (e), the focus of (b), and are adjusted for parallax by means of the screw (e') which permits a slight movement along the axis of the telescope. In the first sights supplied, the vertical wires were double and all were made very thick, which is probably a sound policy for night firing, but they obscured too much of the target; the wires are now single and the effort is made to have them very fine.

40. "Finding sights."—The open-sights (f, f') are the "finding sights" and, if it becomes necessary, may be used to give the final aim; but their radius is only about twelve inches, and the gun can be only roughly pointed with them.

41. Effect of jump.—The sight being subjected to the *jump* of the gun, all its parts must have considerable strength to with-

* Prof. P. R. Alger, U. S. N.



TELESCOPE SIGHT.
Old Type.

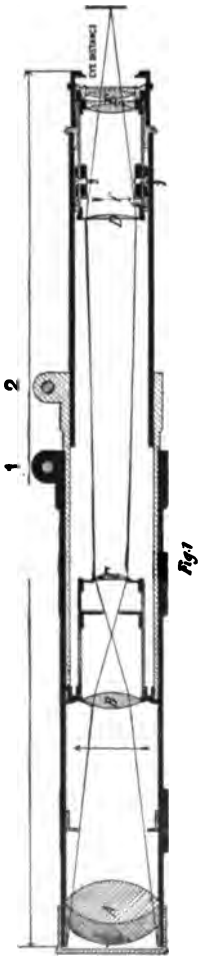


Fig. 1

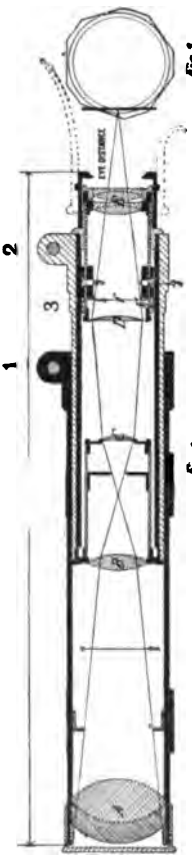


Fig. 2

Fig. 3

THE SAEGMULLER VARIABLE-POWER TELESCOPE.

stand the strain; also, the jump will cause the eye-piece to give a severe blow if the eye is pressed close against it; as a protection, a soft rubber buffer is fitted, against which the pointer rests his cheek.

42. Movement of the eye.—If a piece of paper is held at the point at which the eye is placed, the light coming through the telescope will show as a bright spot about .02 inch in diameter, which is about the size of the normal pupil. If any portion of the pupil is coincident with the bright spot, the image of the target and the cross-wires will be seen. The telescope being of good workmanship and properly adjusted, a movement of the eye across the whole coincidence of the bright spot and the pupil will not disturb the relative position of the image. It is apparent, then, that the head may be moved through nearly 0.4 of an inch without interfering with the sighting, while with an open-sight, to be accurate, the pupil must be held exactly in the line; then, too, the eye may be moved *along* the line of sight somewhat without introducing an error or interfering with the focus.

43. The Saegmuller variable-power telescope (see Plate II) has replaced the first design. In addition to the variable-power feature, these telescopes are much stronger and better able to withstand the shocks of gun-fire.

44. The underlying principle in increasing or decreasing the power of a telescope is found in the fact that the power of any telescope is the quotient of the focal length of the object-glass, divided by the length of focus of an equivalent lens of the eye-piece. The word "equivalent" means a comparison of the magnifying power of the compound eye-piece with that of a single lens of a certain focus; thus a compound eye-piece with the equivalent of one inch has the same magnification as a single lens of one inch focus.

45. The first telescope had an object-glass of about four inches focal length, while that of the eye-piece was about 1.7 inches, giving a magnification which was thus about 2½ diameters.

46. Increase in power.—If we can change the power of this eye-piece to an equivalent of say ½ inch, it is clear that the resulting power will be eight. In this particular instrument the

construction is such that the equivalent may be reduced to .4 of an inch, which, with the same object-glass of the old telescope, gives a magnification of exactly ten.

47. The change in power is accomplished by adjusting the two systems of lenses which compose the eye-piece; when separated they form a high-powered glass; when brought together a low-powered telescope is the result; this is shown by the plate. It may be seen that the difference lies in the points at which the lenses (*B*) and (*D*) intercept the pencil of rays, depending upon the amount of convergence or divergence that has taken place, and directly affecting the size of the resultant image.

48. To adjust for power.—With the addition of this feature, the telescope is the same as the old form and has the same lenses. To adjust for power, slacken the clamp (1) and set the tube which contains (*B*) and (*C*) to the desired power by the scale (3); set up (1).

49. To focus.—The instrument remains to be focused, which is done by slackening the other clamp (2) and setting the rear tube, which contains (*D*), the cross-wires, and (*E*), until the telescope is in focus.

50. Eye-distance.—With an eye-piece of ordinary construction, the power cannot be changed, for the lenses have to be of specially computed curves and some of them have to be achromatic to avoid color around the images. This is particularly the case with (*C*) and (*E*). It is desirable that the distance of the eye from (*E*), the "eye-distance," be considerable, to give space for an elastic cushion for the eye. This distance changes with the power, and a lens of special construction is used to give an eye-distance sufficiently great at all powers; this distance should be as much as one inch.

51. The "apparent" field of any eye-piece is the angle subtended at the eye-point by the diameter of the diaphragm, and the "effective" field is found by dividing the "apparent" field by the magnifying power of the telescope. Thus it will be seen that with an increased eye-distance we have to increase the diameter of the diaphragm so as not to reduce the field, which again changes the dimensions of the various lenses.

52. Practical limit of power.—The tendency is now to increase the power of the telescopes because, under good conditions of light, more accurate pointing may be accomplished with the greater magnification. Necessarily this decreases the field and the eye-distance, and a low-powered sight is more suitable in poor light or with the ship rolling heavily. Because of this great range in required power, it may become advisable to fit each gun with both high- and low-powered telescopes. Or the idea of using both high- and low-powered eye-pieces with the same object-glass, as proposed by Lieut. Mustin for a prismatic telescope-sight, may be adopted. For battleships' guns, firing under favorable conditions, magnifications of from 15 to 20 have given good results, in spite of the necessarily small field.

Telescope-Sight Mountings.

53. First type.—As before stated, to be successful, the telescope-sight must be mounted on a non-recoiling part of the mount that partakes of all the motions of the gun, in train and elevation; for intermediate and secondary calibers, this part is the gun-slide. At point-blank range, the optical axis of the sight is parallel to the axis of the bore; at greater ranges, the two axes must form an angle equal to the required angle of elevation. Thus in setting the sight for a particular range, the telescope is depressed to that extent; then if its axis—the line of sight—be pointed at the target by the pointing gear of the gun-mount, the gun will be raised to the necessary angle of elevation. This is exactly what occurs in sight-setting, but the ranges which correspond to the angles of elevation instead of the angles themselves are marked on the sight-bar.

54. When first adopted, telescopes were mounted on the gun-slide and the first type—on the "pedestal" mounts—remained for several years without being improved, although those sights were very defective. There was no arrangement for azimuth setting of the sight; its accuracy of installation depended upon the care with which its "box" was machined; its height above the deck changed as the gun was moved in elevation, causing the pointer to follow it up and down with his eye; and, finally, the entire

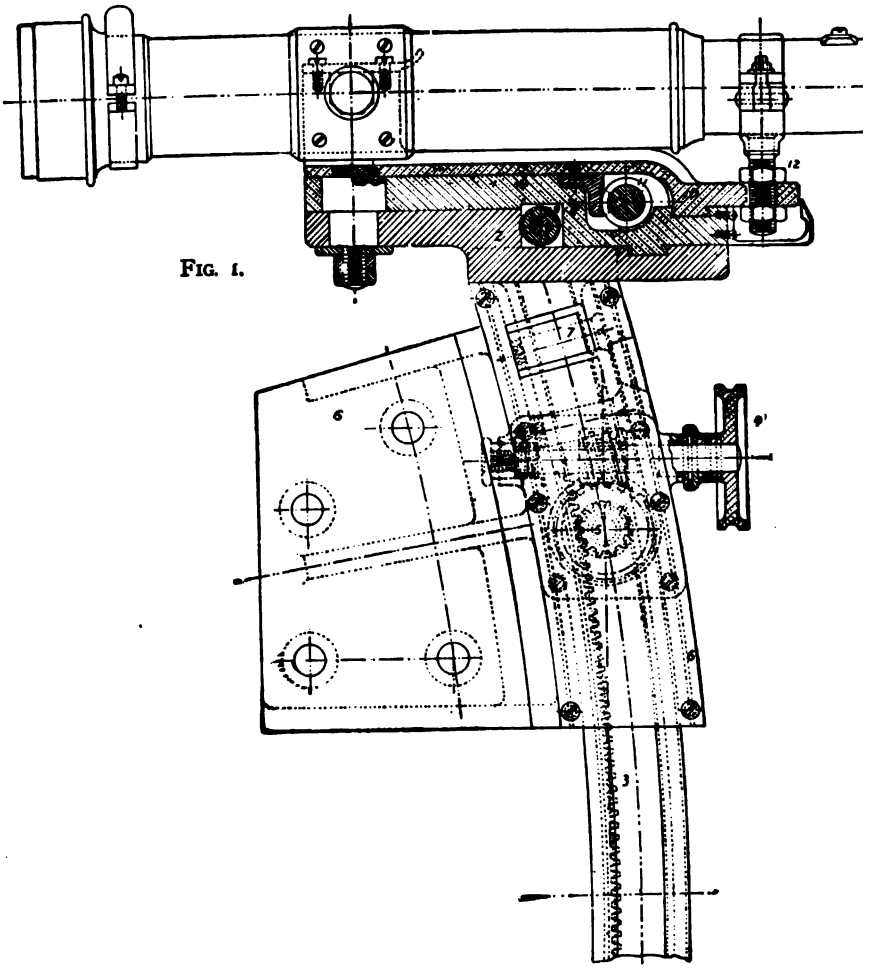


FIG. 1.

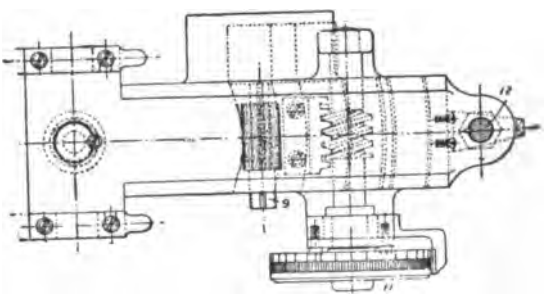


FIG. 3.

TELESCOPE SIGH

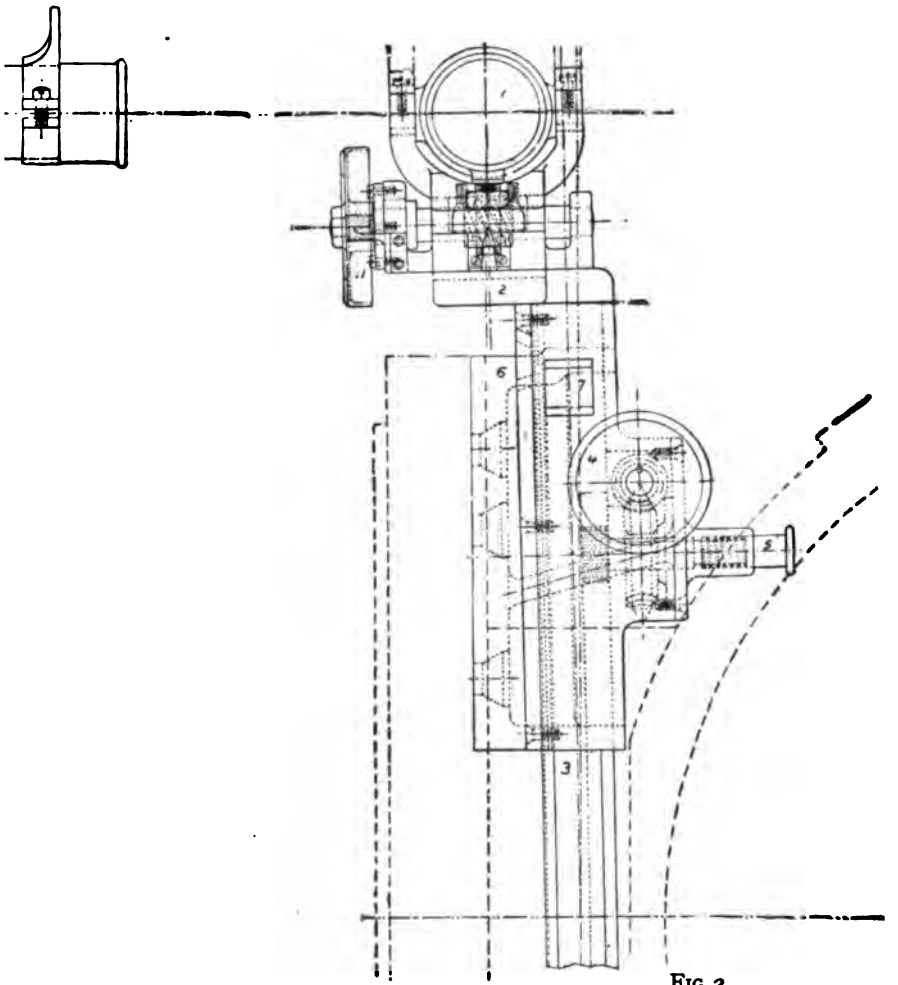


FIG. 2.

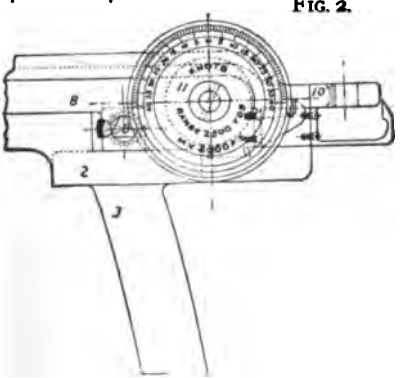


FIG. 4.

FOR 5-INCH GUN.

sight and mounting was so fragile that it could with extreme difficulty be kept in adjustment during firing. These defects made it so troublesome an instrument that, after five or six years' use, it was seriously proposed to discard it entirely and revert to open-sights. The next type, described below, is in many respects an improvement, and it is now in extensive use; however, the type is not at all satisfactory and will be replaced.

55. The "sword" mounting (see Plate III) keeps the telescope at a constant height above the deck and provides for azimuth setting; but its construction is not sufficiently strong and the accuracy of installation depends upon the machining of the small surfaces of the sight-box. Fig. 1 is in section and side elevation; Fig. 2, in rear elevation; Fig. 3, a plan, and Fig. 4, a view of the transversing drum.

56. *The telescope* (1) is secured to its table by trunnions near the outboard end, to permit adjustment in elevation, and at the rear end by an upright and collar and the adjusting nuts. The base of the stand (2) is drawn out to form the *sword,* a long sight-bar (3), which is an arc of a circle whose center is at the center of the trunnions; the ranges and other legends are marked on its right and rear sides as in "bar" sights. The sight-bar ships in a sight-box (6), bolted to the gun-slide, having openings (7) near the top, through which the ranges may be read. The telescope is given an angular motion in the vertical plane by raising or lowering the sight-bar, by means of a hand-wheel (4) which gears through worm- and pinion-gearing with the toothed rack of the bar; the worm-gearing is interposed to prevent the sight from being jarred down. If a quick movement of the bar is to be made, disconnect it from its gearing by pulling the shaft (5) to the right, disengaging its spur-wheel, whereupon the bar may be moved up or down by hand.

57. *To compensate for drift,* the entire sight-mounting is inclined to the left through one degree—the allowance made with all main-battery telescope-sights when this type was adopted.

58. *The sight is set laterally* by a device which corresponds to the sliding-leaf of open-sights. The table (10), to which the sight is directly secured, is pivoted at its forward end and its rear end has a dovetailed lip fitting in a groove in the lower table (8).

The table is rotated horizontally by a double-threaded worm which is turned by the transversing drum (11); the bearings of the worm, which gears in a small arc screwed to the upper table, are in the lower table; its threads are of steep pitch. The amount of offset given the telescope is indicated by a scale on the transversing drum, shown in detail in Fig. 4; a pointer extending rearward from the lower table also gives a reference mark and acts as a check on the drum.

59. *A permanent lateral correction* may be given the telescope by a device similar to the above—the lower table swinging on the stand (2) on the same center; the arc, however, is stationary and the shaft (9) of the transversing worm, which has very low pitch, is also secured to the lower table (8); no scale, giving the permanent offset is needed, as the shaft (9) is turned by a key and cannot be moved without it.

60. *Any permanent vertical correction,* necessary because of inaccurate workmanship, etc., is made by adjusting the top and bottom nuts of the threaded upright (12) which attaches the rear end of the telescope to the *upper* table; during this adjustment, and at this time only, the telescope moves on its trunnions.

61. Sights for pointers and trainers.—When telescope-sights first came into use, one gun-pointer was required to point, both in train and elevation, as well as to fire, and only one sight, which was on the left side of the gun, was fitted. Subsequent developments having shown that a separate trainer is essential, we find, first on the guns having the "sword" mounting, an open-sight on the right side for the use of the trainer. It has been shown that with open-sights vertical *visual* errors are the more likely to occur; since only the elevating pointer, using a telescope-sight, actually fires the gun, the accuracy of fire depends upon him and it was deemed sufficient if the trainer pointed somewhat roughly in train as well as in elevation. Therefore the trainer was at first given an open-sight which he himself was required to set, roughly in elevation and as accurately as possibly in azimuth, while working his training-wheel; the other pointer, at this time, had a sight-setter for his telescope-sight. The next step, a recent one, lies in providing a telescope-sight for the trainer as well, and the sight described below is the exact counterpart of the first pointer's sight on the left side; a sight-setter is necessary for each sight.

It may be mentioned here that, in the newest designs, the firing-attachments provide for firing from the right as well as from the left side of the mount; they may be arranged to permit either of the pointers to fire, at the same time cutting out the opposite side, or both may be connected at the same time.

Pivot-Bar Sight.

62. The 5-inch sight, Mark XII (Mod. 3), shown by Plate IV, is being fitted on board many ships; there are several modifications of the mark, involving changes in detail, but the one shown is typical. All the views are in profile, Fig. 1 from the right, Fig. 2 looking down, and Fig. 3 from the rear. The sight is called the "pivoted-bar" sight.

63. The two sights are fixed to the top of the "sword" (3) as in the older type, which is raised and lowered in its box by the hand-wheel (4) through gearing in exactly the same way, but accuracy of installation does not depend upon the machining of the sight-box. The latter is a part of the bracket (6), which is bolted to each end of the gun-slide with its two parts connected by a bar, as shown. The sight-holder (14) is fixed to the pivot-bar (8), which is connected, through the azimuth setting-device, to the sword. The forward end of (8) forms a ball-and-socket joint (15) in the forward part of the bracket, thus giving the other end freedom of motion. Therefore, instead of depending upon a surface in the sight-box of barely two inches, there is a radius of 42 inches to govern the direction of the sight; lost motion has less effect in just this proportion and the whole mounting is very strong and durable.

64. The scales (7) are white metal strips, dovetailed into the surface of the sword; permanent adjustments of the sight are made by altering the positions of these strips; for this purpose the securing screws pass through elongated holes. The holder (14) has longitudinal motion along the pivot-bar, having a feather working in the slot (18), so that the sight may be slid along the bar and adjusted to suit the gun-pointer.

65. The telescope (1), of the variable-power type, is rigidly clamped in the right compartment of the holder.

66. The peep-sight.—On the other side there is a peep-sight (5), outwardly similar to the telescope, with a one-tenth-inch peep-hole in a diaphragm in the rear end. The corresponding front-sight (16) is a ring with single cross-wires; it is adjustable, both horizontally and vertically, to permit the peep-sight to be brought into coincidence with the telescope. The night-sight (17) is in line with the cross-wires; it is explained in full below. The forward end of (5) is not closed.

67. Eye-buffers.—Both the peep- and the telescope-sights are fitted with rubber eye-buffers; they protect the pointer's cheek from the blow of recoil, aid him in retaining his eye in the line of sight, and are most essential parts of any peep- or telescope-sights.

68. The azimuth-setting mechanism of this sight is distinctive. As already explained, the forward end of the pivot-bar works in a universal joint and the rear end may be moved laterally as well as vertically. On the rear end of the bar there is bolted an azimuth head which fits over the top of the sword by a dovetailed groove, the sides of which are arcs of circles with (15) as a center. The shaft of the azimuth hand-wheel (11) has its bearings in the sword and carries a worm which engages a corresponding rack on the surface of the azimuth head; the sight may thus be moved in azimuth by turning (11). Instead of having the azimuth scale graduated for one fixed range, as in the first sword-mounting, this sight may be set in azimuth for any range up to 6000 yards without further calculation, by a direct setting on the scale.

69. The vertical azimuth plate (10) is secured to the rear side of the sight-box by screws through elongated holes, to permit permanent lateral adjustments. The pointer (12) of the pivot-bar fits close over the face of the azimuth plate, the height of which is equal to the vertical movement that is given to the pointer when the sight is raised from 0 to 3600 yards. The pointer rests on the lowest deflection line when the sight is set at point-blank range. From the zero deflection line of the azimuth plate, curves of deflection of 10 yards each, extending to include 170 yards for the 3600-yard range, are laid off to the right and left, each being plainly marked.

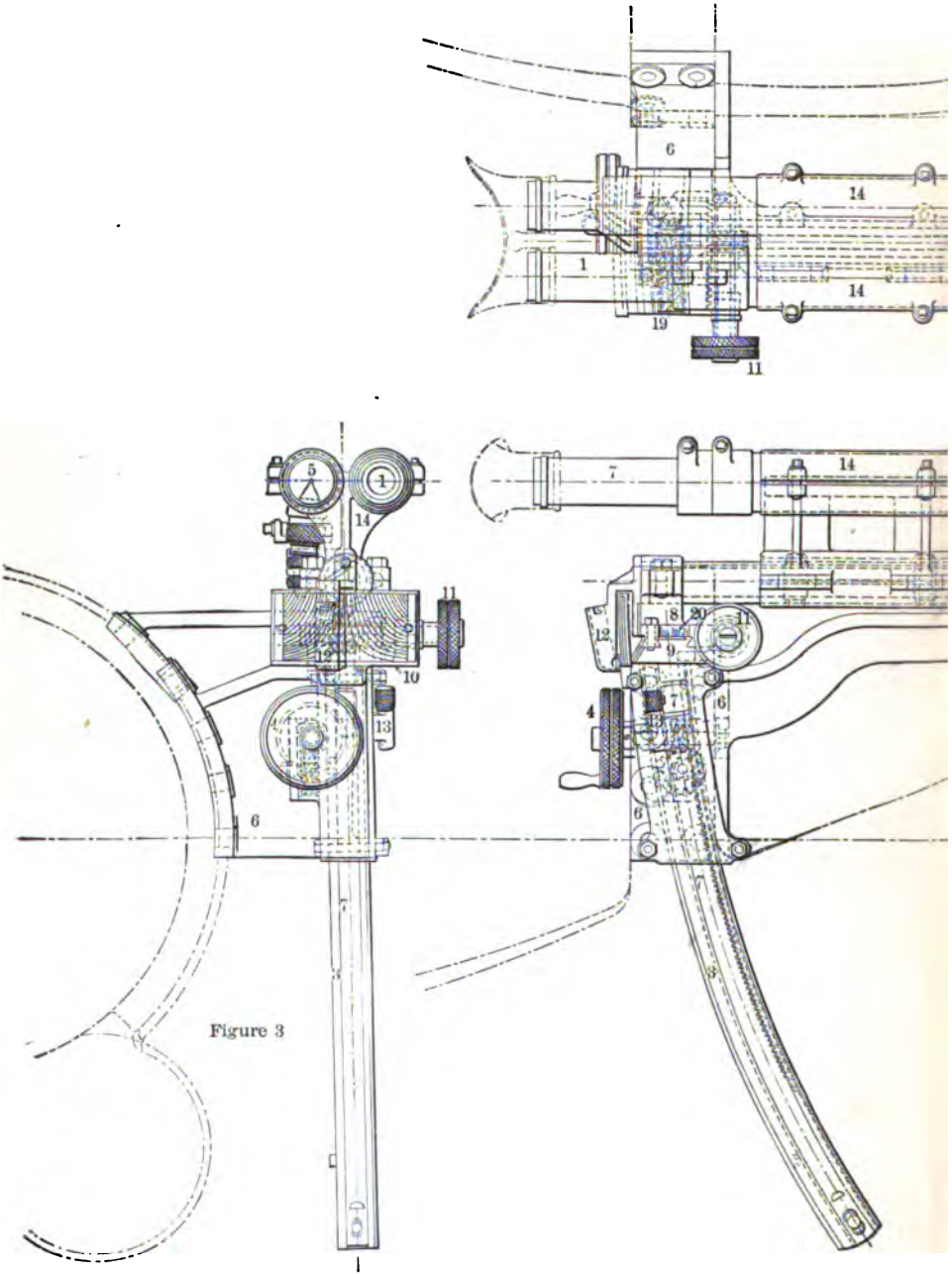


Figure 3

THE V-INCH SIGHT,

Pivot-Ba

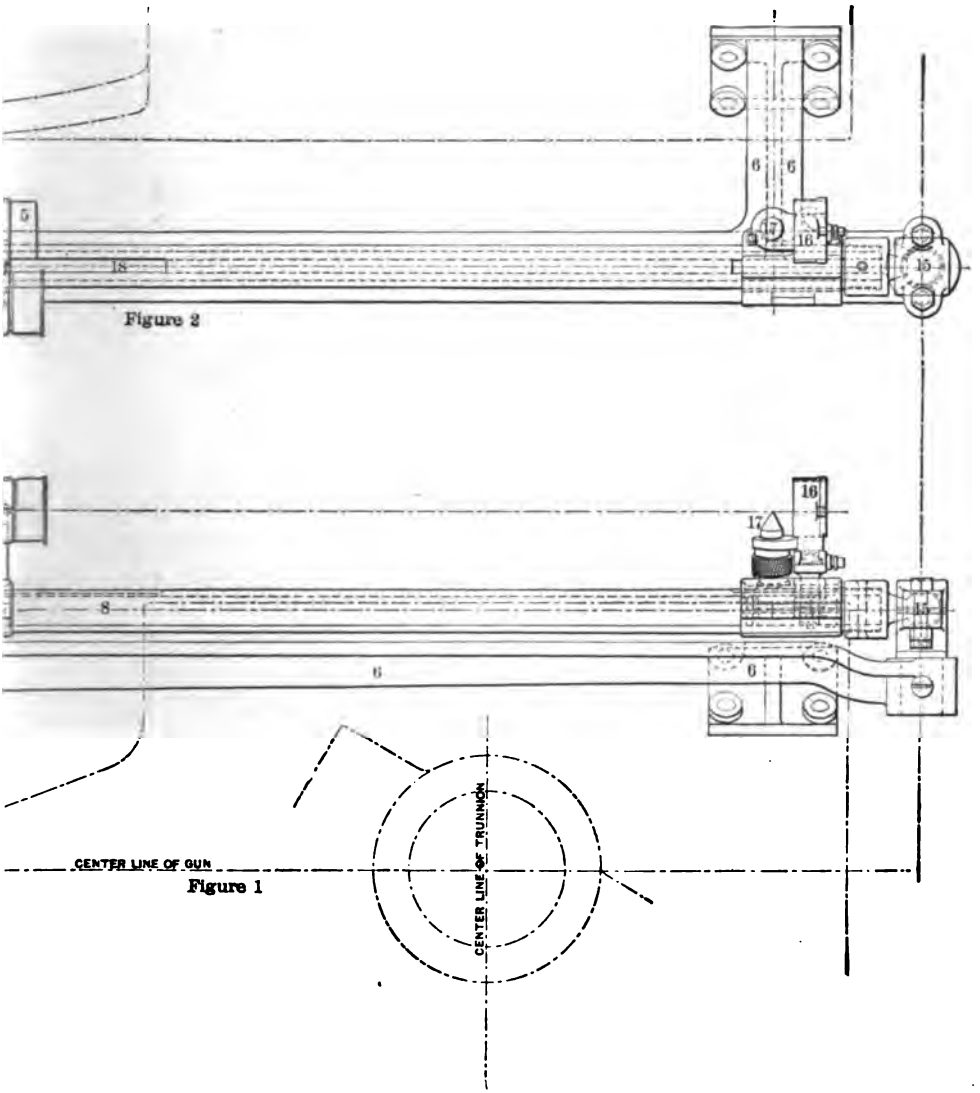


Figure 2

Figure 1

MARK XII (MOD. 3).

r Sight.

70. Obviously, for the same amount of deflection, less movement of the sight is required for long ranges than for short ones; hence the curves approach each other at the top, as may be seen in Fig. 3. Between 3600 and 6000 yards, the *horizontal* azimuth scale (19) is used; it is secured to the top of the sword by two screws passing through elongated holes. It also has deflection curves of 10 yards each extending, for 6000 yards, to 140 yards right and 210 yards left; the zero line is drawn 1.25 inches to the right of the center line of the mounting to bring it clear of the azimuth head, when the sight is amidship; this accounts for the greater scope of the scale to the left. There is no pointer corresponding to (12) to set on this scale and the horizontal scale (20) on the azimuth head, which is marked from 3600 to 6000 yards in 200-yard intervals, takes its place. To use the horizontal azimuth plate, the foot of the vertical line on scale (20) that corresponds to the range on the sight-bar is placed on that curve of the azimuth scale which gives the deflection required. The two azimuth scales are thus continuations of each other.

71. To compensate for the drift of the projectile, this particular modification of the mark has its mounting inclined one degree to the left end. This necessitates giving the zero-line of the vertical azimuth scale the same inclination. The zero-line of the horizontal scale has a slightly greater inclination to the left, which has the effect of adding to the deflection given by the inclination of the sword. The drift increases relatively faster than does the range and to exactly compensate it the zero-line of the scale should be a curve; this is the system followed for the later modifications, most of which are installed with the sight-sword vertical. The curvature of the middle line of the scale increases with the range and the deflection curves are laid off from it.

72. The left-sight is exactly like that described except for the differences in the brackets, etc. Each sight is virtually independent of the other, but a connecting-bar for joining the two pivot-bars is supplied to each gun. The length of the connecting-bar is the same as the distance between the pivots of the two sights, giving, when in use, a parallel motion to the pivot-bars; when the azimuth-setting worm of the trainer's sight is disconnected, the sights will be set alike in azimuth, *provided they are kept at the*

same elevation. The connecting-bar is attached to the pivot-bars by trunnion-blocks, and, so far as it is concerned, the sights *may* be set differently in elevation. But it will readily be seen that if the left sight is changed extensively in elevation, without being followed by the right-sight, the connecting-bar will be canted and the azimuth head of the trainer's sight will be forced one way or the other; if this disparity in setting becomes great enough, the head will strike against its stops and, if forced, will deform some of the parts. In order to have the same azimuth reading, when the connecting-bar is in use and the right azimuth worm is disconnected, the sights must have the same reading in elevation. Therefore, the trainer's sight must be set as accurately as the other and two sight-setters are needed.

3-inch Sight, Mark VII.

73. The 3-inch sight, Mark VII, is shown by Plate V. All the views are in profile; Fig. 1 is from the left side of the gun, Fig. 2 looking down, and Fig. 3 a view from forward.

74. Difference between 5-inch and 3-inch sights.—The main point of difference in this mounting, over that described above, is in the cross-connection device which is permanent and an integral part of the mounting; it is always in place and only one sight-setter is to be used. The left pivot-bar (8), which has a 28-inch radius, is firmly secured in a socket in the yoke (15). The short pivot-bar on the left side is also rigidly secured to the yoke and the construction is massive enough to insure that the two bars shall always be parallel. The vertical center of the system is a short stud projecting downward from the center of (15) to its seat in the rocker (19); the latter has flanges, drawn from the stud as a center, which provide bearings for the guides of the yoke (15). When the sights are moved in azimuth, the system pivots on the center of the stud of the yoke; the bearing surfaces of (15) and (19) are accurately machined and prevent any canting of the system. The horizontal center is the heavy bolt (21) which secures the rocker to the saddle (20); the latter is firmly bolted to the sleeve of the mount. The trainer's sights (1) and (5), are clamped in a holder on the short bar (22), close to the

yoke and necessarily have the same motion as the left-sights. There are no scales and no setting mechanism on the right side; the only adjustment for this sight is to move it along the bar to fit the trainer. The sights proper are the same as for the 5-inch Mark XII mounting, except that the night-sight on the left side may be dropped clear of the cross-wire field for day use.

75. The sight-setting mechanism is similar to that of the older type of pivot-bar sight. The sword (3) is operated by its hand-wheel (4), as shown in the section. The scales (7) are adjustable in their grooves, for permanent corrections. In addition to the ordinary range-scale (7) the ranges may be read on the range-dial (23) which has more open graduations. Its pointer (24) is stationary and the dial itself is revolved through gearing as may be seen in the section. There is a spiral groove in the dial which follows the range graduations and works a small slipper along the top of the pointer (2); this slipper is actually the pointer. The azimuth setting is made by (11) through mechanism very similar to that described above.

76. The azimuth deflections are given by the deflection curves, reading to yards, on the azimuth drum (10). The scale, which is scribed on a sleeve capable of adjustment on its drum, may be used up to 4000 yards. The bearings of the drum (10) are a part of the sword-head and, since the scale is raised with the sight, its zero deflection line is at the top and the pointer (12) is stationary. When the pivot-bar is moved to the right or left by (11), the azimuth drum is revolved by a rack on the pivot-bar which engages a small pinion on the shaft of the drum; the pointer then gives the deflection corrected for, by its position on the scale. The pointers (12), (13), and (14) are fitted with small lamps for night use.

77. Advantages.—This mounting insures parallelism of the two sights, has a very open range-scale, requires but one sight-setter, and is a distinct advance over the others. If practicable, the same cross-connection device is to be extended for use on larger guns.

Night-Sights.

78. Telescopes at night.—If the target is illuminated enough to show in a telescope, telescope-sights give good results at night, provided cross-wires can be seen. The searchlights appear to diffuse light enough for this, and low-powered telescopes have been successfully used under these conditions. High-powered telescopes probably will not admit enough light.

79. The night-sight shown in Fig. 7 was issued for use on those guns that were equipped with the first sword-mountings.

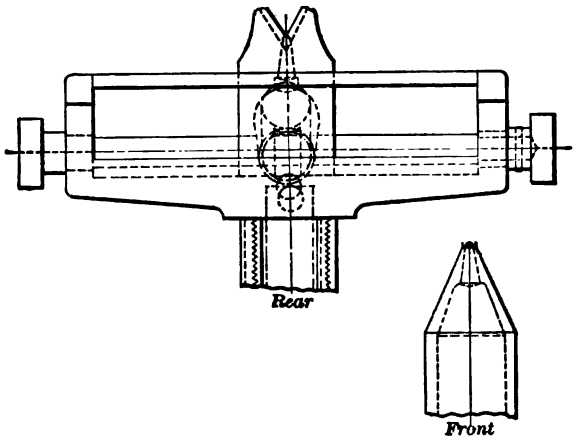
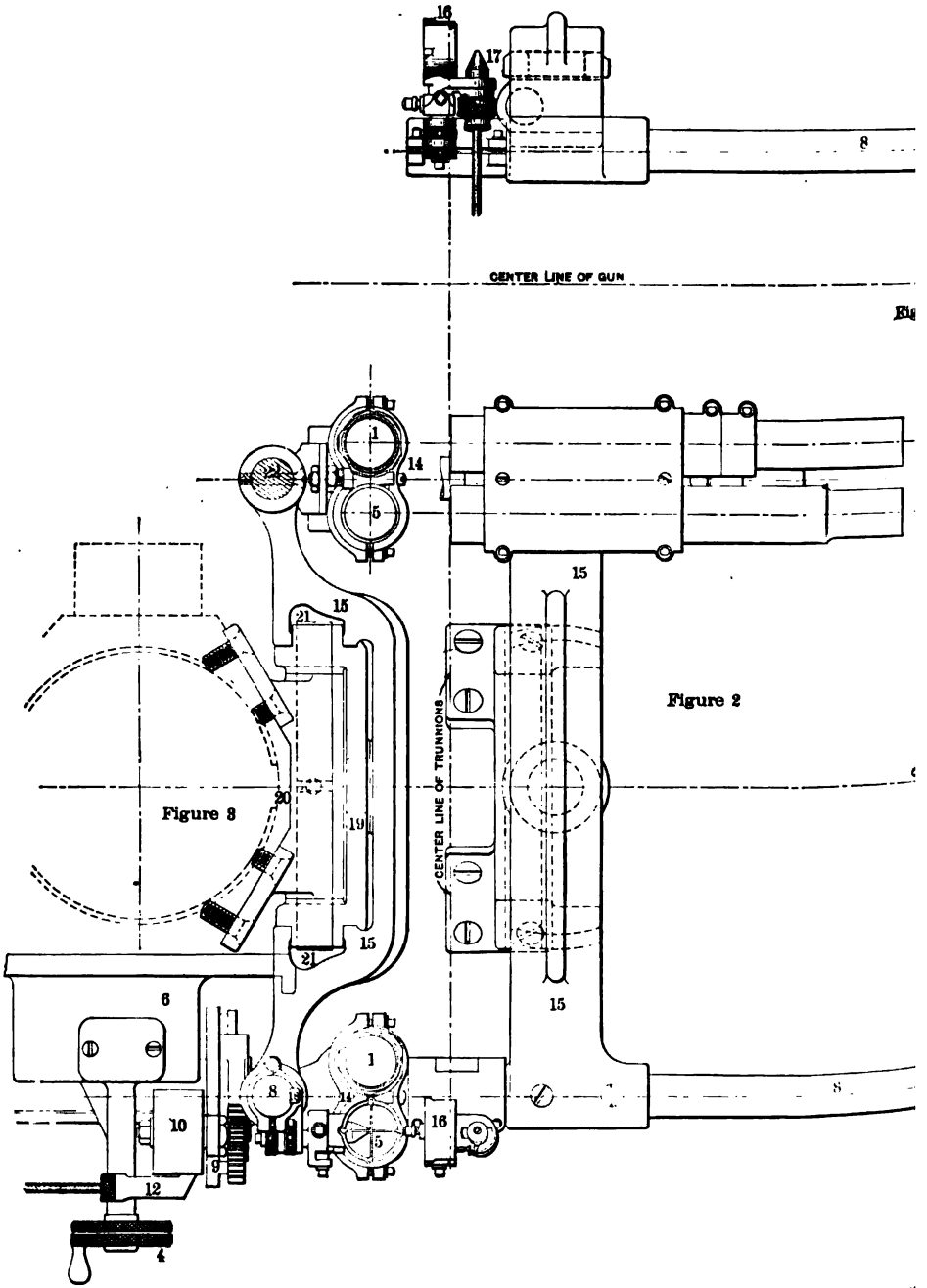


FIG. 7.

It is an open-sight with notched rear-sight on a sliding-leaf, and, in outward appearance, it is an ordinary "bar" sight; thus it may be used in daylight if the telescope-sight is disabled. The rear sight-bar, with ranges, time of flight, etc., marked on inlaid white metal strips, is raised and lowered by a device like that for the sword-mounting; the bar is inclined to the left to compensate for drift. Set in the tip of the front-sight and in the bottom of the rear sight-notch are small pieces of differently colored glass; front-sight red, rear-sight white or green. The sights are hollow from below and each contains an incandescent light of very low candle-power which takes current from the firing-battery. (A typical arrangement of the sights and the wiring for the night attachment


16
17
8
CENTER LINE OF GUN
1
14
5
15
21
15
CENTER LINE OF TRUNNIONS
Figure 2
Figure 3
20
19
15
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6
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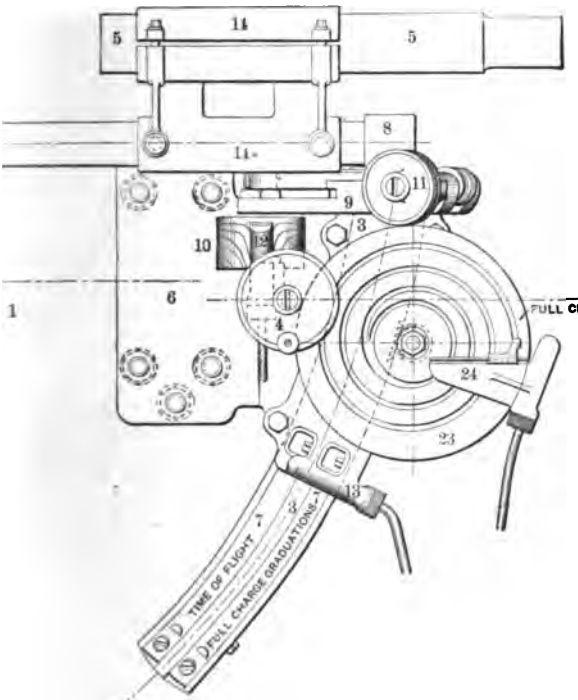
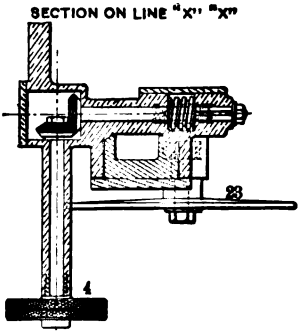
4

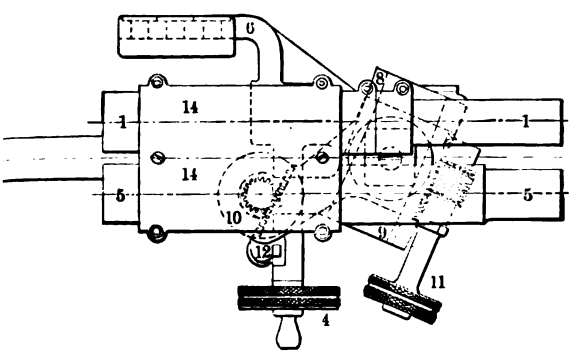
3-INCH SIGH



SECTION ON LINE "X" "X"



NTER LINE OF GUN



MARK VII.

is shown in Plate III of the preceding chapter.) When in use on a dark night, the two sights will show two small spots of light of different colors, and the gun is pointed by aligning them on the target. A successful way of using it is to keep the front-sight dim and turn off the lamp of the rear-sight, since the notch will be well defined by a dim battle-lantern.

80. The front-sight of this design is retained in the newest sights, in which it is combined with a rear peep-sight. In using either, care should be taken lest the firing battery be exhausted by keeping it turned on the sight for long periods; also its full strength may burn out the lamps.

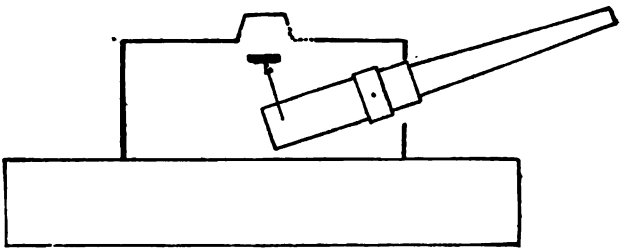


FIG. 8.

SIGHTS FOR TURRET-GUNS.

81. All turret-guns are fitted with telescope-sights for the trainer and for the pointer of each gun, who elevates and fires; the later turrets have in addition auxiliary "day and night" sights for the pointers at least.

82. Sights cannot be mounted directly on the gun-slide of a turret-gun because too large an opening in the turret would be required when firing at an elevation; Fig. 8 illustrates this—without a much larger gun-port the target will rarely be in view from the sight while the ship is rolling. To obviate this, the sight is placed in a hood in the turret-roof, and being close to the front side of the hood, only a small opening in it is needed. To give the telescope the same angular motion that the gun-slide has, it is mounted on a table which is connected to the slide by a parallel motion device, upon which the accuracy of the mounting largely depends.

83. The arrangement in use in the earlier turrets is shown by Plate VI. The trunnions of the telescope rest in an upright similar to that of the mounting used for the first telescope-sights, and the sight-setting apparatus is also the same—there is no transversing mechanism for correcting lateral errors.

84. In the figure, (*M*) is a *cross-shaft* whose axis of rotation is parallel to the axis of the trunnions (or pivot bolts) of the gun. Upon this shaft is keyed the arm *E M* of the telescope standard *b c*, the latter terminating in a base *b*, hinged at *d* to the arm and capable of giving a slight permanent adjustment to the line of sight in the *vertical* plane by means of the screw *a*. The standard is forked at its upper end to support the trunnions of the telescope *A B*.

85. Keyed to the cross-shaft *M* is the arm *M P*, which is connected by the connecting-rod *P O*, to a point on the slide, at *O*. *N* is the pivot of the slide; the length of the arm *M P* = the distance *N O*, and *P O* = *M N*; there is a turn-buckle in *P O* to correct any lack of parallelism between *M P* and *N O*. The joints are all accurately finished and are locked to prevent lost motion. It is plain that any angular movement of the slide (and consequently of the gun) communicates a corresponding movement to *M P* and to the telescope *A B*.

86. A drum *D*, graduated spirally for the range of the gun at different angles of elevation, is fitted to a triple-threaded screw *e* which bears upon an arm *K* rigidly attached to the telescope, so that, by turning the drum to indicate any marked range, the telescope is depressed through the corresponding angle, and this angle of depression is the angle between axis of bore and axis of telescope,—when the system is in perfect adjustment. Therefore when the drum *D* is set for any desired range and the telescope is directed upon the target by elevating the gun, it follows that the gun is laid at the proper elevation.

87. The base (*b*) is made in two parts, held together by bolts which pass through slots in the upper plate and set up in the lower one. When the bolts are slackened, the upper plate may be revolved on the lower by the tangent screw (*t*) and thus make a permanent correction in the horizontal plane; this is only for

adjusting the sight and is not arranged to be used as a sliding leaf. Drift is compensated by slightly lowering the left trunnion of the telescope.

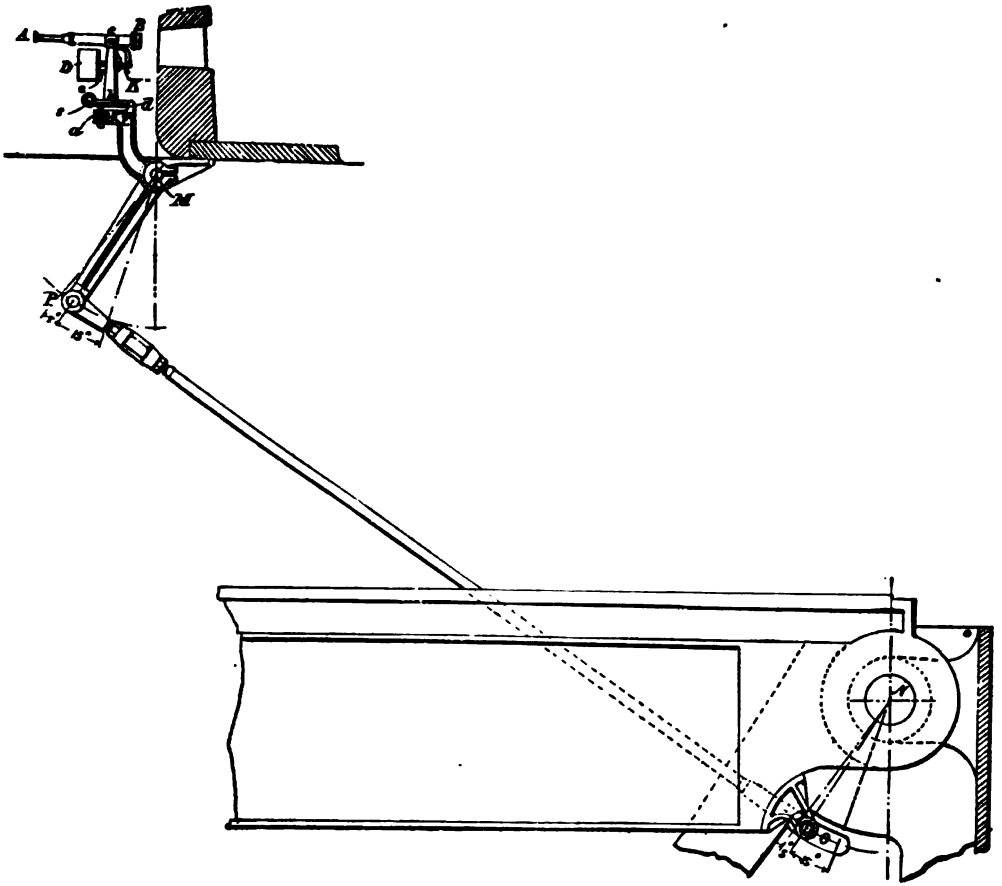
88. The system of parallelism described above was installed for all turret-sights, but the details, for different turrets, differ somewhat; one change is to make all parts stronger and better able to withstand the severe shock of discharge. In one system, used in several turrets, the sight is not attached to the turret, or sighting hood, at any point whatever, but is entirely supported by a heavy bracket (1) that extends upward from the deck-lugs and bears the cross-shaft and all the sight-mounting (see Plate VIII). In still later turrets the mounting is secured to the inside of the hood somewhat as has been shown in Plate VI. In all of these systems, however, the range-scale is marked spirally around a drum and the telescope is depressed or elevated in much the same way. An elevation indicator, which shows the elevation of the gun, in degrees, with respect to its platform, is, in all but the earlier turrets, connected to the sight-mechanism and is installed in plain view of the gun-pointer; he lays the gun to its loading-position by it.

89. Defects of first turret-sights.—This general type of turret-sight, as outlined above, is at present installed in most of our turret-ships. In addition to having, in most cases, its parts too weak to withstand the severe shocks of firing without being thrown out of adjustment, these sights have the following inherent defects:

(1) Range-scale too short and not open to facilitate quick and accurate sight-setting; the sight-setting mechanism not arranged to be readily accessible to the sight-setter.

(2) All parts subjected directly to the jump of the gun on firing and eye-piece of the telescope at a considerable distance from its center of motion, which causes it to give the gun-pointer a severe blow when the gun recoils, as well as at the end of its counter-recoil.

(3) A system of parallel motion in which lost motion due to looseness or wearing of the parts causes an error in the sight which is relatively very great; no adequate provision for taking up such lost motion.



TELESCOPE SIGHTS FOR THE EARLIER TURRET-MOUNTS.

NEW TYPE OF TURRET-SIGHT.

90. New type.—To correct these defects, Lieutenant H. C. Mustin, U. S. N., has designed a turret sight-mounting which has been officially adopted and is being installed in many ships. Plate VII shows a preliminary design for a 13-inch turret, which illustrates the system of parallel motion with clearness. In the finished design, some of the details, particularly those concerned with the azimuth-setting mechanism, may be modified. Fig. 1 is from the right of the right gun, for which the design is made, and Fig. 2 is looking down.*

91. The standard (4), bolted to the deck-lugs in the usual manner, furnishes bearings for the cross-shaft (*a*) which is the horizontal center of the sight's motion, when the gun is moved. Pivoted on the cross-shaft is the heavy bracket (1), with a radius of over five feet for a 13-inch gun, which bears the sight itself and the entire setting-mechanism. The connection with the gun is through the flanged sector (3), to which it is connected by its rollers (6). The sector is permanently bolted to the gun-slide; its roller-paths are arcs of circles, upper one drawn from *X*, with the distance *a Y* as the radius. The parallelogram of motion then is *a Y X Z* and the only points at which there may be lost motion are at (*a*) and (*Z*); any slackness that is caused by the inevitable wear from constant Morris-tube practice may be readily removed by substituting new rollers and a new bushing at (*a*). The axis of the lower roller is borne by the movable block (7) which is forced upward by a spiral spring so that any slight wear of the rollers is automatically taken up; of course if this wear becomes very great, the system will be thrown somewhat out of adjustment. To relieve the mechanism from wearing during routine exercises, the spring may be kept slack. An important function of this device is to yield upward when the gun is fired and thus cushion the jump. With reasonable care, this system should always be capable of giving the sight the same angular motion as has the gun.

92. The sight-bar (2), to which the telescope is directly secured, has for its horizontal center the supplementary cross-shaft

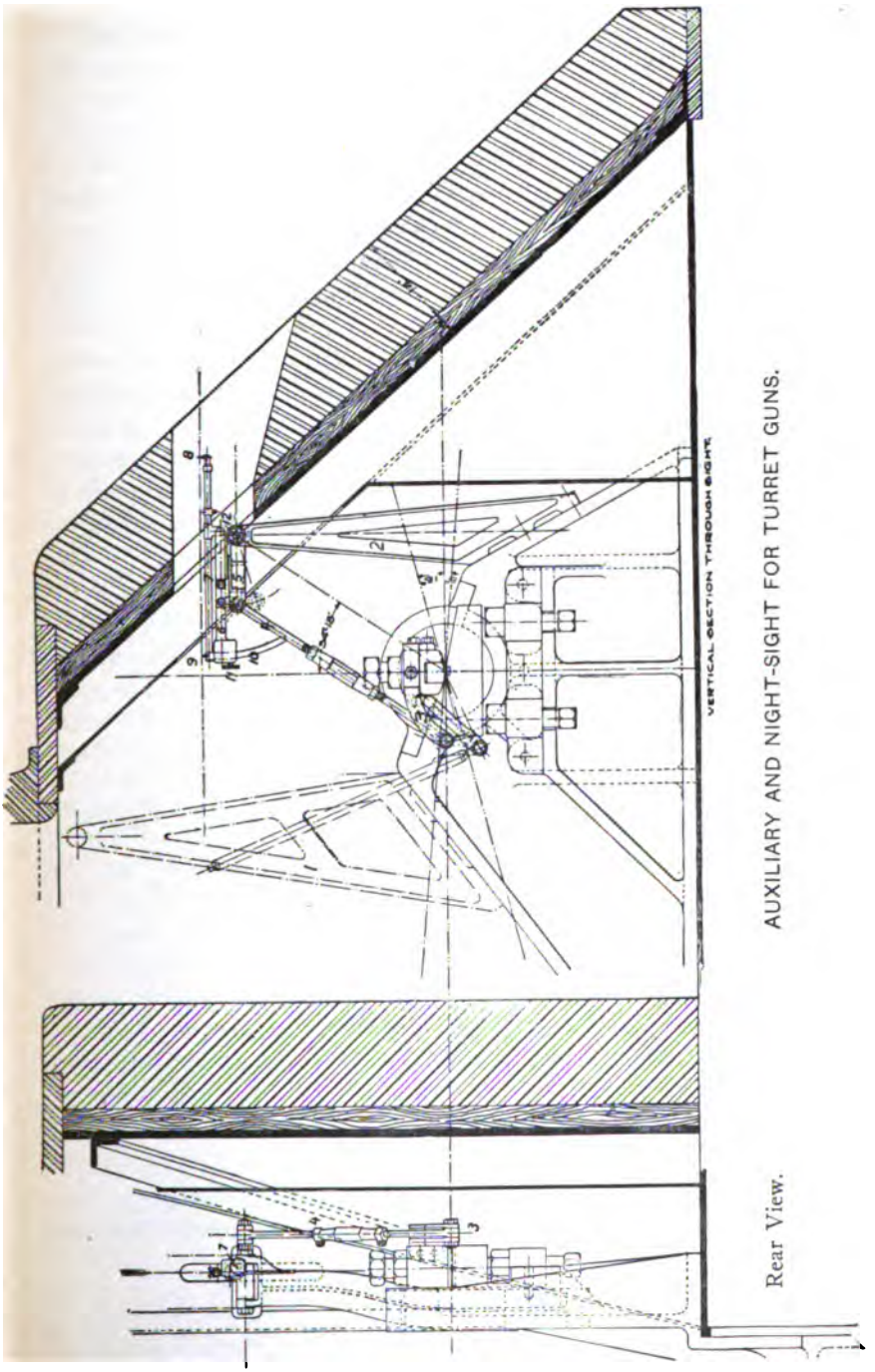
* A parallel motion system of this class was devised by the late Lieutenant Haeseler, U. S. Navy, as long ago as 1898, and sights on his design were installed in the turrets of the U. S. S. Texas.

(*b*), with bearings in the bracket (2); this shaft is also bushed with brass, as are all of the working surfaces. The lower end of the sight-bar has a block (5) which works in a circular slot in the lower end of the bracket; the center of curvature of this slot is the center of (*b*). The block (5) is moved up and down in its slot by the threaded shaft (10), which is revolved by the hand-wheel (8). In this way the sight is given the required angle of depression below the gun's axis, that is, the sight is set. The scale of ranges (9), a very open and finely divided one, is scribed on the bracket and a pointer on (5) moves over it, indicating the range. It is to be noted that the eye-piece of the telescope is close to (*a*) and should permit the gun-pointer to keep his eye at the telescope while the gun is fired.

93. Azimuth-scale.—The sight-bar has also a vertical pivot, a bolt with bearings in (18), on which it swings for azimuth sight-setting. Working horizontally in the sight-bar block (5), there is an azimuth-worm which is turned by the setting-wheel (11). It moves the rear end (12) of the sight-bar along a slot in the block, resulting in motions of the sight in azimuth; the azimuth-scale (13) is, for this design, on the top of the block. The two hand-wheels are thus convenient for the sight-setter who is to remain on the floor of the turret. This mounting has given satisfaction on trial and it appears to have been proven as free as is possible from the defects mentioned in Art. 89.

94. The trainer's sight for turrets is a telescope-sight secured to the inside of the training-hood and not connected to the guns in any way. The duty of the trainer is to keep the axis of the turret, with which each gun is parallel, in the vertical plane between turret and target; hence it is unnecessary, not to say inconvenient, to have the training-sight partake of the movements of the guns. Accordingly, its trunnions are horizontal and the trainer may swing it up and down on them to keep the target in its field—its independent movements are in the vertical plane. There is, however, a transversing drum, marked with the ranges, and the trainer must keep it set at the range of the pointer's sight to give his sight the same drift compensation.

95. Night-sights for turret-guns are on the same principle as



AUXILIARY AND NIGHT-SIGHT FOR TURRET GUNS.

Rear View.

those for intermediate guns; those supplied to the pointer's hoods of the Alabama class, and many subsequent ones, are shown by Plate VIII. The sight and mounting are supported by the bracket (2) bolted to the deck-lug; the sight is installed below the hood and is used through a sighting-hole in the front-turret armor. Parallelism between the sight-base (6) and the gun is secured by the arms (5) and (3) and the connecting-rod (4); the latter is fitted with a turnbuckle by which large vertical errors of adjustment are corrected; the axis (12) must be parallel to the axis of the trunnions. The front- (8) and rear-sight (9) are both attached to a bar (7) pivoted at the forward end of the sight-base and capable of motion in a vertical plane (corrected for drift) about its pivot. To the rear end of the bar a toothed sector (10), on which are marked the ranges, is secured; the geometrical center of the sector is the pivot of the bar. The function of the hand-wheel (11) is to raise and lower the sector by connecting gearing and thus give the sight the required angle.

96. *As installed, these sights are not placed conveniently* for the gun-pointer. It is likely that in the future a peep-sight with illuminated cross-wires in the forward end of the barrel will be arranged by the side of each of the telescopes for night firing.

Adjusting Sights.

97. Causes of errors.—Unless needless errors in pointing are to be introduced, the axis of the bore and the line of sight must be parallel when the sight is set at zero. It is not likely that the workmanship in machining and installing the different parts of the sight-mountings will always be sufficiently accurate, and, even if that be the case, a little wear or deformation of some part may affect the parallelism, and only great care and watchfulness on the part of the division officers will insure the efficient condition of the sights. With most sights, means are furnished for correcting the unavoidable errors of workmanship, etc.; these adjusting devices have been described, or at least mentioned, for a few of the many varieties of sights.

98. The bore-sights are supplied to ships to give a line in prolongation of the axis of the bore while adjusting the sights; one

of them is placed in the muzzle, the other in the breech of the gun. The front-sight is a bronze ring, with cross-wires fixing its center, that fits neatly over the lands of the rifling; the rear-sight, containing a short telescope whose optical axis is in the geometrical center of the sight-ring, is placed in the rear end of the powder chamber or resting in the blanks of the screw-box. The field of the telescope is at least as large as that subtended by the bore, and it is so constructed that the cross-wires of the front-sight and a distant object will both be in focus.

99. Accuracy of bore-sights.—With bore-sights, a gun may be pointed with extreme accuracy; in testing armor, or in firing through a screen to measure the jump, the pointing is done in this way. The telescope supplied with the service bore-sights may have a prohibitive amount of parallax; it is good practice, in all cases, to cover the eye-piece with a disk of paper having a pin-hole in its exact center; the eye then will receive only the central rays and make the parallax inoperative.

100. To test a sight of any type, direct the gun at a well-defined object, not nearer than 1500 yards if practicable (to make parallax between the two lines inappreciable), by means of the bore-sights. Then, with sight set at zero, note whether the line of sight is also directed at the target; if not, alter the sight by the adjusting screws and bolts until it does and set up hard on all nuts and set-screws. When the ship is not motionless, two observers, one at the bore-sights and one at the regular sights, are needed; with care they may attain a degree of accuracy by "marking" when the sights are on the target selected, but it is greatly to be preferred if the tests can be made with the ship motionless; adjusting sights at sea is difficult and rather unsatisfactory.

101. Before testing telescope-sights for parallelism, the telescopes should be seen to be clean and in good order. Unless the object-glass is always screwed in to the same extent, the optical axis may not be the same; a line scribed on its frame must tally with one on the telescope-barrel. Of course, the telescope must be in focus; the pointer who is to use the sight should always be used in testing. The only adjustment that is frequently needed in the telescope itself is to place the cross-wires in the exact focus

of the eye-piece, where the image is formed. Unless this is done, the wires will appear to shift across the target when the eye is so moved as to take in different portions of the pencil of rays—that is, the cross-wires will have parallax. In all telescope-sights the wires are carried in a circular frame which may be moved along the axis of the telescope until the exact point of focus is obtained, and clamped to the barrel by a screw.

102. For long ranges.—The sight and its mounting having been tested and adjusted for point-blank range, it only remains to ascertain if it is also correct for firing at longer ranges, with the sight at different settings. Obviously, all sights on any gun must travel in parallel planes as the sights are raised and these planes must be vertical or at the slight inclination to the vertical that is designed to compensate for drift. These tests are best made by using battens at an accurately measured distance from the sight; it is also good practice to test, in the same manner, the correctness of the graduations of the range and azimuth scales; these have been found to be sometimes in error, particularly for the azimuth scale.

103. Distance between the sight and the bore.—With all but turret-guns, the line of sight and the axis of the bore are near enough to each other to be considered coincident. In turrets, however, where the sights are several feet above the guns, accurately aimed shots will strike a corresponding distance from the point of aim—if the line of sight and axis of the bore are parallel, as they usually are for the smaller guns. Hence, while adjusting preliminary to such fine shooting as is called for on record target-practice, the object on which the adjustment is made should be at the same distance as the target to be fired at. Then, if the adjustment be made with sight set at zero, the two lines will make a small angle with each other which should cause the projectile to strike the point at which the sight is directed.

104. Effect of shocks.—The telescope-sights of heavy guns, and in particular those of turret-guns, are subjected to severe shocks, while firing, which are likely to cause derangement, no matter how carefully the sights are secured. For this reason it is an advantage to have some means of readily testing the sights, at any time during the firing, without recourse to the bore-

sight. Of course, ingenuity in utilizing the local resources is valuable and the same ideas cannot be carried out under different circumstances; one method that may be used in the central hoods of hydraulic turrets is to depress the telescope, the gun being level, until the edge of the turret-roof can be seen; note the range that the drum is set at and project the cross-wires on the turret-roof in differently colored paint; then, to test the sight at any time, level the gun and set the sight at the proper range, when, if the sight is still in adjustment, the cross-wires will cover the painted lines. This, with other similar methods, is very rough, but, even so, it is well to be able to tell instantly if the sight has been extensively changed.

105. An objection has been raised to the adoption of telescope-sights, on the plea that they are of necessity too delicate, and add to the number of sensitive instruments to be cared for. It is true that they are delicate, but not so much as a sextant or a chronometer—two instruments so essential to the safety of the ship that they are under the sole personal care of one of her senior officers. In times of peace, the gun-sights are perhaps not so important; but under war conditions, which the navy strives to live up to, any officer would prefer losing the chronometers instead of as many turret gun-sights, the latter at such times being the *more essential to the safety of the ship.* This being the case, a navigator's care and watchfulness over his instruments may well be lavished upon the sights of the battery by division officers and gun-pointers. As regards care of matériel, it is their most important duty, and on its thoroughness largely depends carrying out the doctrine: *"The only shots that count are those that hit."*

CHAPTER XXII.

SEMI-AUTOMATIC GUNS.

1. A semi-automatic gun is one in which a portion of the energy of firing is utilized to perform a *part* of the loading and firing operation for the succeeding round, the remaining part, usually comprising merely the insertion of the cartridge, being done by hand. Such guns may be constructed in any size, but the different systems involving the principle are utilized mainly for secondary-battery guns.

2. In the U. S. Navy, all 1-, 3-, and 6-pounders now building are being constructed on semi-automatic systems and probably no more ordinary rapid-firing guns of those sizes will be constructed for ship's secondary batteries. The systems in use are the Maxim-Nordenfelt, the Hotchkiss, and the Driggs-Seabury. (A few 6-pdrs. of the latter type have been built by a private firm.) It is likely that the 3-inch guns also will be "S. A." in the future.

3. Semi-automatic guns have well-defined advantages over those of ordinary R. F. types, and some S. A. systems obtain these advantages with very few added complications:

(1) The rate of fire is greatly augmented; unaimed shots may be fired at the rate of nearly one per second. So great is this increase that *automatic* guns, above rifle caliber, though capable of firing much more rapidly, seem no longer necessary, considering the greater weight and the complicated mechanism entailed by such systems.

(2) A portion of the labor of loading being performed automatically, one of the gun's servants may be dispensed with.

(3) Since the block opens only during counter-recoil, the danger from "hangfires" is diminished; it is only necessary to wait and the block cannot be opened prematurely, if the hand-lever be let alone.

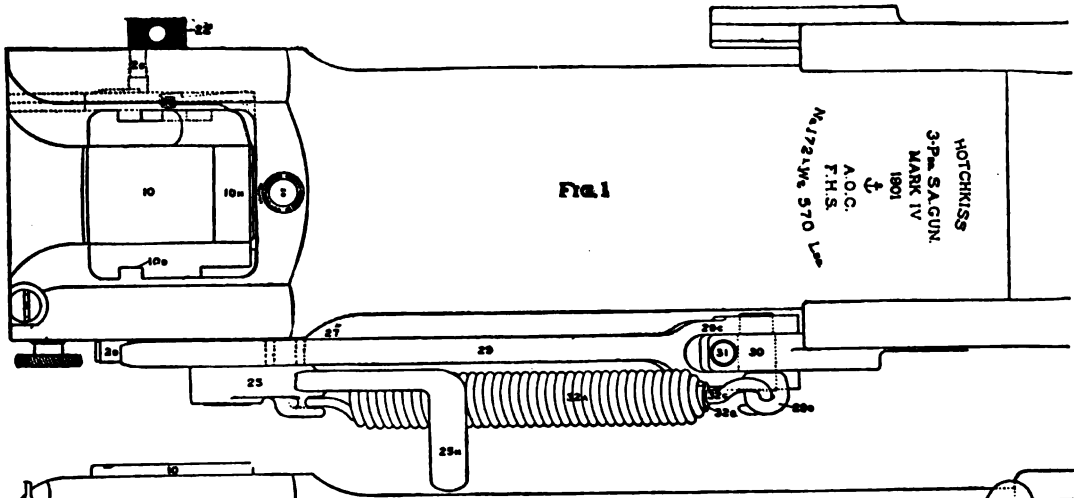


Fig. 1.

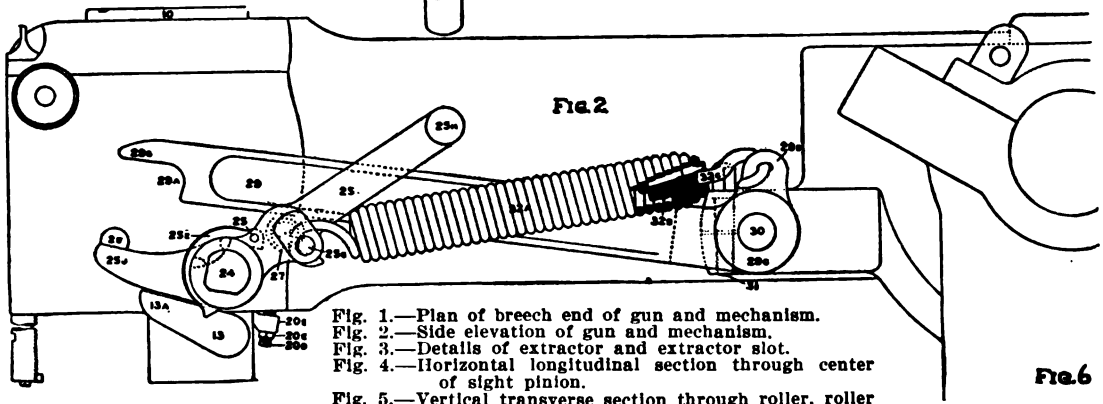


Fig. 2.

Fig. 3

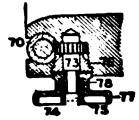


Fig. 4

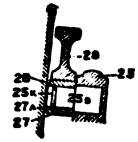


Fig. 5

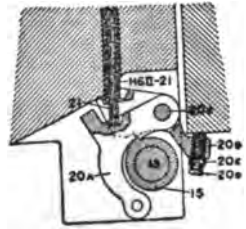
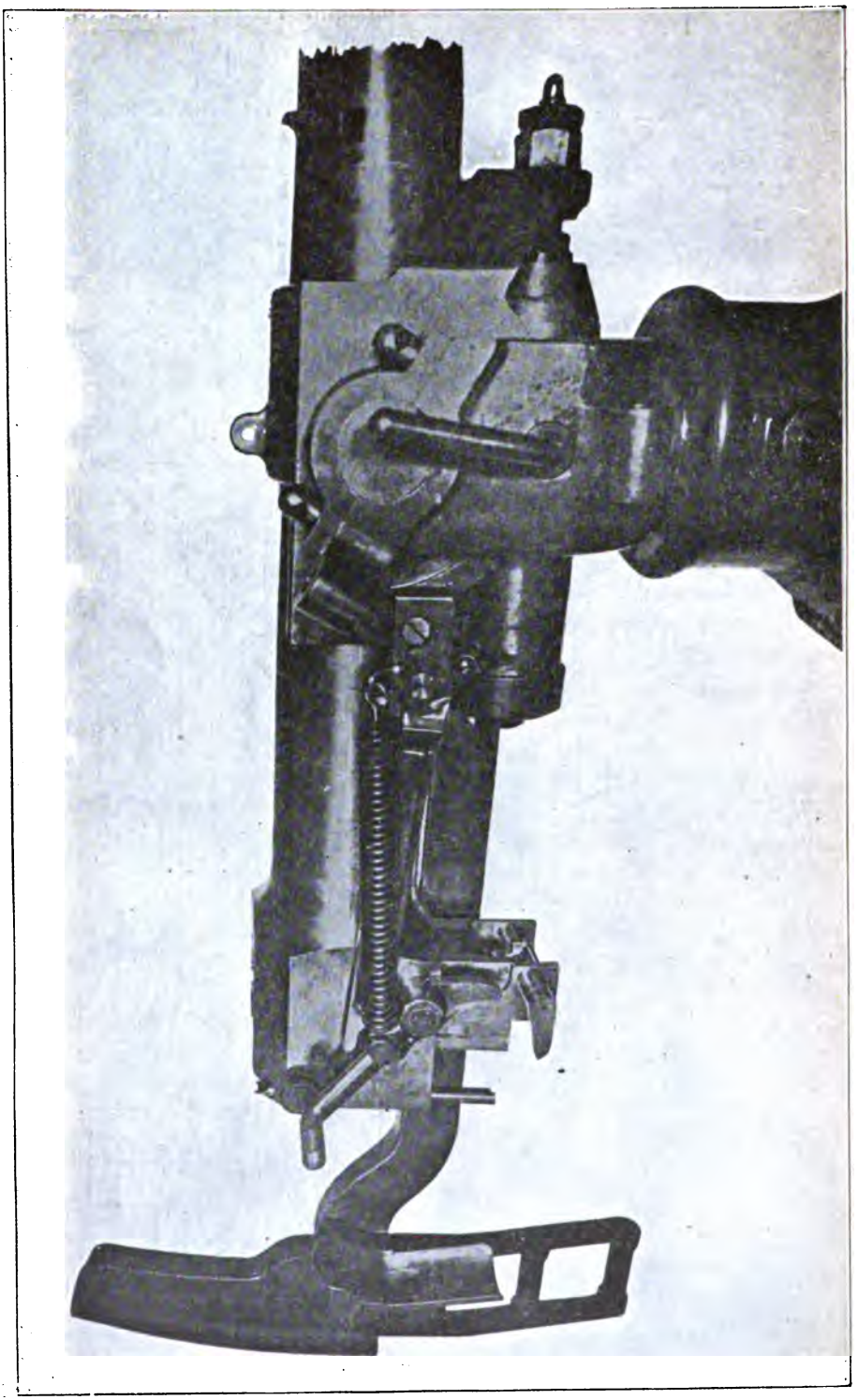


Fig. 6

Fig. 1.—Plan of breech end of gun and mechanism.
Fig. 2.—Side elevation of gun and mechanism.
Fig. 3.—Details of extractor and extractor slot.
Fig. 4.—Horizontal longitudinal section through center of sight pinion.
Fig. 5.—Vertical transverse section through roller, roller pivot, operating lever, and thrust rod.
Fig. 6.—Vertical longitudinal section, immediately to the right of sear, of a portion of the breechblock.

HOTCHKISS 3-PDR. SEMI-AUTOMATIC GUN.



POSITION OF PARTS OF 3-PDR. SEMI-AUTOMATIC MECHANISM WITH BREECH OPEN.

(4) The automatic closing of the block is less likely to derange the pointer's aim—the gun being pointed by a shoulder stock—than if it be done by hand, which constitutes a very great practical advantage.

The Hotchkiss Semi-Automatic System.

4. This system belongs to that class in which the opening and closing of the breech are performed by energy stored during recoil in the counter-recoil and "breech-closing" spring. Besides the advantages claimed for it in the way of lightness, simplicity, accessibility of parts—none of which are complicated or delicate—certainty of operation, etc., the Hotchkiss R. F. guns now in service may be readily made semi-automatic. Guns with the device are now in service and it bids fair to be largely adopted for the 1-, 3-, and 6-pounders, and perhaps for 3-inch guns. All guns so fitted, including the 1-pounders, are built-up steel guns consisting of tube, jacket, and screwed locking-ring. (The mechanism for a 45-caliber, 3-pounder gun is shown by Plates I and II.) The range of the 3-pounders is 5200 yards, M. V. 2200; of the 1-pounders 3600 yards, M. V. 2100.

5. The breech mechanism is in all the ordinary features like the Hotchkiss Mark II mechanism described in a previous chapter, the block, stop-bolt, crank, rock-shaft, hammer, firing-spring, etc., being the same. The differences lie in the extractor (23), the sear (20),—to which a safety device has been added,—the operating lever (25) and in the addition of the breech-closing spring (32) and the thrust-rod (29).

6. The sear mechanism (20) consists of five pieces; its functions are to retain the hammer at full-cock, until released by a pull on the trigger, and to prevent the release of the hammer when the breech is open; it has nothing to do with the semi-automatic part of the mechanism and can be fitted to ordinary Hotchkiss, Mark II mechanisms.

7. The *sear-trigger* (20A) is pivoted on the sear-pin (20C), which is held in a cylindrical hole in the right side of the breech-block. In the upper side of the trigger (Fig. 6, Plate I) is a small pocket for the end of the sear-trigger spring (21). This

spring is seated, in company with the sear-pawl spring (21H, Fig. 6), in a vertical cylindrical pocket in the breechblock; the two springs are wound in opposite directions. Referring to Plate I, it will be seen that the cock-notch of the sear-trigger engages the cock-notch on the hammer, the hammer being cocked. The lug on the sear-trigger just below the figures 21 serves as a stop when the lanyard is pulled; this prevents the sear-trigger from being pulled far enough back to actuate the sear-pawl—if it were possible to actuate the sear-pawl by a pull on the lanyard, then the hammer could be released with the breech open. In the lower end of the sear-trigger is an eye through which the lanyard is rove.

8. *The sear-pawl* (20B) is pivoted on the sear-pin between the two legs of the trigger and has in its upper side a pocket for the lower end of the sear-pawl spring; it has a stop-lug and a cock-notch similar to those of the sear-trigger. On its lower end are the sear adjusting-screw (20D) and a locking-nut (20E). The functions of the sear-pawl are to hold the hammer at full-cock, when the breech is open, and to release it onto the sear-trigger, when closed; the function of the sear-springs is to press downward on both the trigger and pawl so that the cock-notches on them will engage that of the hammer whenever opportunity offers. The adjusting-screw (20D) is for adjusting the pawl, so that, when the breech is closed, the adjusting-screw will strike on under face of breech-housing and lift cock-notch on sear-pawl clear of hammer. The nut (20E) serves to lock the adjusting-screw in position.

9. *To adjust the sear-pawl,* open the breech, come up the locking-nut and partially unscrew the adjusting-screw; now close the breech and hold back the trigger—it will be found that this will not release the hammer. Now screw in the adjusting-screw until it takes under the face of the breech and forces the pawl down just far enough to release the hammer which, if the trigger is not held back will be caught by it, giving a slight click. This adjusting should be nicely done, so that when the breech is closed slowly the sear-pawl will not fail to trip, nor trip too soon.

10. The function of the extractor is to eject the empty case in the usual manner and then to hold the block open until a new

cartridge is inserted. (See Figs. 1 and 3, Plate I.) The extractor slides forward and backward in a T-shaped groove, being actuated by a lug travelling (relatively) in the extractor-groove of the breechblock as in the ordinary Hotchkiss R. F. mechanism. The stop-pin (2c) passes through the curtain of the gun into the extractor-housing and has a notch in its inner end. The extractor-claw (23b), pivoted at the front end of the extractor, has an arm extending to the rear outside the extractor-slide (23a) from which its rear end is forced outward by a small spring (23d). When the breechblock is lowered, the extractor moves to the rear and ejects the empty case; the end of the extractor-claw is kept pressed against the stop-pin and, as the limit of rearward motion is reached, the notch (2d) snaps over the stop-pin (2c). This prevents the forward motion of the extractor, and consequently the upward movement of the block, until the extractor is released by the new cartridge striking its claw and forcing its tail inward, whereupon the mechanism is free to close. With each gun, a plain extractor is furnished for use when the gun is operated without the S. A. attachment.

11. **The operating lever** fits over the end of the crank-shaft, to which it is secured by a lock (25e) as in the Mark II mechanism; the cocking-cam also is unchanged—when the breech is closed it brings up against the stop (2B). The end of the lever is bent outward at right angles, forming the handle (25h), and the breech-closing spring hooks over a pin (25c) in its side. A short projecting arm on the inner side of the lever bears a roller (27) against which the thrust-rod strikes to open the breech. The breech-closing spring (32a) hooks to the lever and to a short arm of the thrust-rod; its hook (32c) allows a limited adjustment in the tension of the spring.

12. *The thrust-rod* (29) is pivoted to the right side of the slide of the mount by the pivot (30), which is held fast in the slide by the thrust-rod pivot clamp-screw (31). The eye (29D) receives the hook of the breech-closing spring. The thrust-rod notch (29A) and toe (29B) will be considered when the operation of the mechanism is described.

13. **Operation of the mechanism** (starting with the breech open).

(1) In this position the breech-closing spring, which is attached at one end to the eye of the thrust-rod, and at the other to the pin on the operating lever, is distended. The tension of the spring on the thrust-rod causes it to bear with considerable force on the roller; this pressure on the roller continues in all positions of the operating lever. The breechblock is held open by the extractor as before described. When the cartridge is entered in the chamber, the rim of the case hits the extractor-nib a slight blow; this releases the extractor-claw from the extractor stop-pin, and the block is closed by the breech-closing spring, the cartridge-case being forced home in the chamber by the loading slope on the block.

(2) Just before the block reaches its closed position, the sear adjusting-screw takes on the under face of the breech, and, as the block closes, causes the sear-pawl to revolve about the sear-pin until its cock-notch disengages the cock-notch on the hammer; this leaves the hammer held in its cocked position by the sear-trigger alone. In firing, a pull on the lanyard, which is rove through the eye in the sear-trigger, causes the trigger to revolve about the sear-pin until its notch disengages the hammer cock-notch, when the hammer flies forward and the gun is fired.

(3) *During the recoil of the gun,* the breech-closing spring is distended, and the thrust-rod bears with increasing force on the roller until the gun has recoiled so far that the roller passes to the rear of the thrust-rod notch, when the rod drops until its toe (29B) rests on the roller; when the gun starts to return to battery, the roller brings up against the thrust-rod notch. The counter-recoil continuing, the rod pushes the operating lever to the rear until the block is fully open, when the rod again rides up on top of the roller. This riding up of the thrust-rod on the roller occurs when the operating lever has been pushed so far to the rear that the pressure of the rod is exerted at a point on the roller above the line joining the center of the thrust-rod pivot and the center of the roller pivot. As the breech is being opened, the firing-pin is cocked in the ordinary manner and the gun is again ready for loading.

(4) It will be seen by reference to Plate I that the downward motion of the thrust-rod is limited by the operating lever, on

which the under surface of the rod bears when the lever is in its extreme rear position.

(5) *To open the breech by hand,* pull the operating lever to the rear; to close the breech on empty chamber, pull the operating-lever handle to the rear, then push forward on extractor-claw, so as to raise its notch clear of the stop-pin, then ease the block up with the operating lever. Or, with a screw-driver handle, push forward smartly on the extractor-claw and breech will close automatically. In firing with faulty ammunition, the breech may fail to entirely close; in which case, complete the operation by hand. No strain is to be kept on the lanyard when the breech is closing as this will cause the gun to fire the moment the block reaches its closed position. To remove the breech-closing spring, close the breech, raise the operating-lever lock, and remove lever from crank, when the spring may be easily unhooked and a new one substituted. The new spring should be hooked to the operating lever before reassembling the lever with the crank.

14. The following failures of the semi-automatic mechanism and their causes have been noted at the proving ground.

(1) **Failure to eject empty case after firing.**—This has frequently been caused by slow counter-recoil of the gun; weak recoil-springs or clogged recoil-grooves, may cause failure to eject. If empty case is held by the block so that it cannot be withdrawn by hand, the extractor has failed to hold the block open; this may mean a broken extractor-claw, a broken extractor-spring, or a broken extractor catch-pin.

(2) **Failure of breech to completely close after loading.**—This failure is usually caused by deformed ammunition, which requires more power to seat than the breech-closing spring can exert. Dirt, unburned powder, or other foreign substances in the chamber will cause failure of breech to close.

NOTE.—If the breech fully closes and the cocking-cam rebounds from the operating-lever stop, the cause will be found to be extra friction of the breech-closing spring on the pin of the operating lever. The spring, where it engages the pin, may have opened or may have started to cut; this point should be kept well lubricated. When the operating lever rebounds as above described, it may cause a missfire, as the cocking-toe must cam the operating lever forward before the firing-point can touch the primer.

(3) **Failure of sear-trigger to release the hammer when breech is closed.**—This is caused by improper adjustment of the sear-pawl.

NOTE.—In case the mechanism does not work freely, examine the crank-head and crank-slot for signs of extra friction; if it is found that the crank-head is rubbing in the bottom of the slot, ease it slightly with emery cloth.

(4) **Failure of the breech to open after firing.**—This may be caused by the breaking of the breech-closing spring during recoil; the spring broken, the thrust-rod notch fails to engage the roller during counter-recoil and the breech remains closed.

(5) Another cause is insufficient recoil; the semi-automatic attachment is designed to operate with a minimum recoil of 3.1 inches. Increased recoil may be obtained by removing a small quantity of glycerine from the recoil cylinder.

The Maxim-Nordenfelt S. A. System.

(See Plates III and IV.)

15. This system was devised in England, and guns constructed on it by the firm of Vickers' Sons and Maxim were among the first of the successful semi-automatics. As in the Hotchkiss system, the breechblock—also of the sliding-wedge type—is forced down during the counter-recoil by a non-recoiling thrust-piece and a closing-spring is energized; the extractor holds the block down until it is freed by the cartridge-rim striking against its claws, whereupon the closing-spring raises the block into its place. This action, however, is secured in a manner different from the Hotchkiss system; it is to be noted that flat springs are employed for most purposes. In the U. S. navy the system is fitted to 3- and 6-pounders; some of the guns are foreign built—by Vickers' Sons and Maxim—but are in most respects like those built, or in process of construction, at the gun factory.

16. The mounting consists of a non-recoiling bronze sleeve, that completely surrounds the breech-half of the gun, trunnioned into a saddle whose pivot rests in a cone or cage-stand similar to that for ordinary R. F. guns. The recoil is checked and the

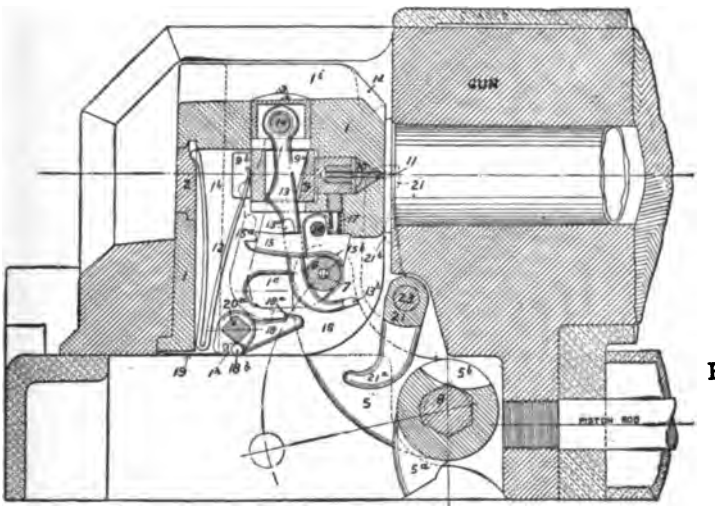


FIG. 1.

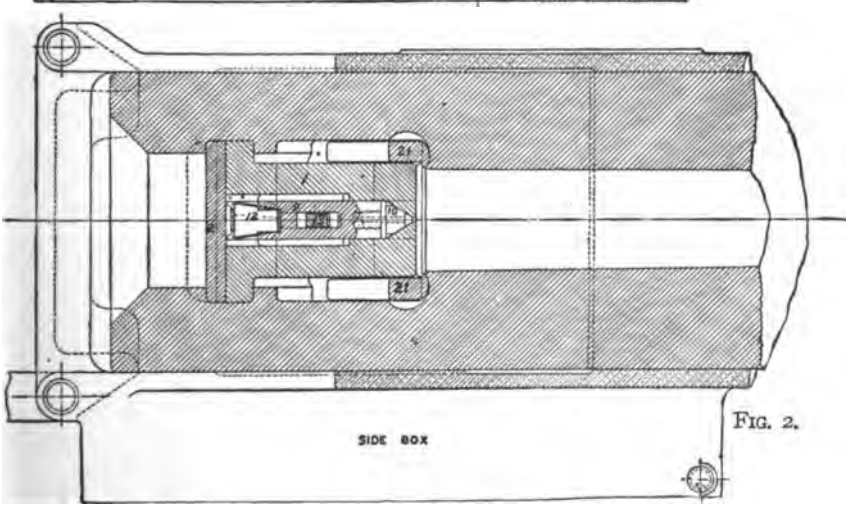


FIG. 2.

FIG. 1. Vertical Longitudinal Section. Breech Closed.
FIG. 2. Horizontal Section through the Axis of the Bore.

MAXIM-NORDENFELT S.-A. SYSTEM.

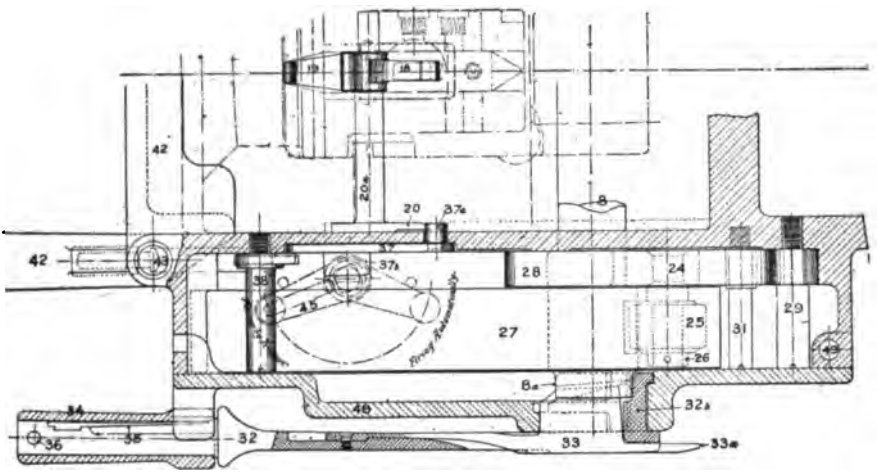


FIG. 1.—Horizontal Section on A. B. of Side-Box and Profile of Bottom of Block.

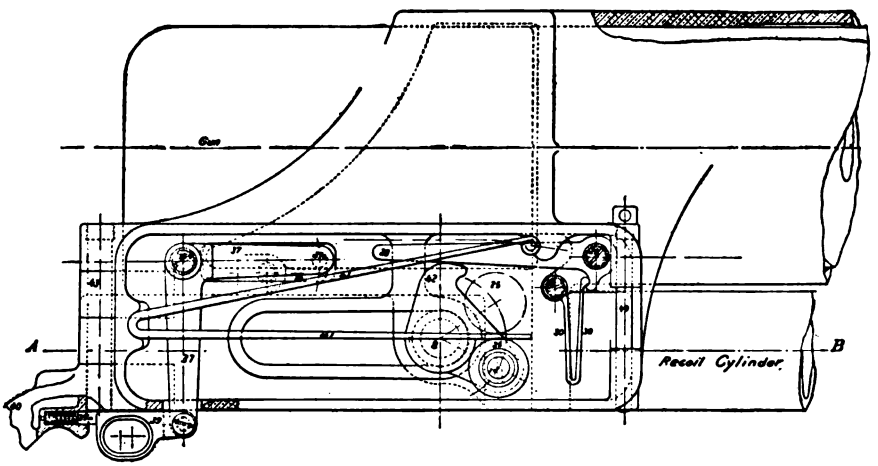


FIG. 2.—View of Side-Box with Covering-Plate removed.
MAXIM-NORDENFELT S.-A. SYSTEM.

counter-recoil is effected by one hydraulic spring-return cylinder. The cylinder, also non-recoiling, is secured to a lug on the under side of the sleeve; it is filled through a filling-hole in the front bonnet and its rear bonnet is fitted with a stuffing-box through which the piston-rod passes to the lug on the gun to which it is secured. The shoulder stock, bearing the rear sight, is secured to the sleeve, which bears the front sight. The right side of the rear end of the sleeve is enlarged to form a box, known as the side-box, which contains the non-recoiling operating gear, trigger, pistol-grip, etc.

17. *The guns are not "built-up"* but are made from single forgings of high-grade steel. The breech is square in section for a few inches and the breechblock housing extends through it from top to bottom; an opening to the rear is left for loading, below which a tie-piece unites the two curtains. From the under side near the breechblock, a heavy lug extends downward, having a threaded socket for the piston-rod and a hinge-pin (8) for the action lever. The mechanism shown in the Plates is that of a 6-pounder, 45-caliber gun giving a muzzle velocity of 2240 f. s.

18. **The mechanism** includes the *breechblock; action-lever; action-lever axis, tumbler, roller,* and *hand-lever; closing-spring; thrust-pawl and spring; extractor;* and the *firing mechanism;* there is no stop-bolt.

19. **The breechblock** (1)—of the same general type as the Hotchkiss block—is hollowed out from the front and bottom to receive the firing mechanism. The recoil is transmitted to the gun from the rear face of the block, which is sloped slightly so that a slight horizontal motion accompanies the vertical movements of the front face; the top is cut away to give room for loading and is sloped downward to the front—to force home the cartridge while closing. There are two notches (1d) in the front upper corners by which the extractors hold the breech open; the rear low corner forms a lip which limits the upward motion. The cam-shaped slot (1c) extends through the block from right to left; the action-lever pin (6) works back and forth in it to raise and lower the block, which is also limited in its downward motion in this way. The pins or shafts of the sear and of the cocking-bar pass through the sides of the block. A dovetailed

plate (2) gives access to the firing-pin and affords a bearing for one branch of the firing-spring.

20. The action-lever (5) is held on and turns with its hexagonal axis (8); it has two arms which embrace the block and bear the pin (6) which is secured by a locking-pin (7). The lug (5a) limits the downward swing of the lever and consequently the downward motion of the block. The axis (8) is inserted from the right and its round portions rest in bearings in the gun; the lever and axis move together through an arc of about 60 degrees. The tumbler (42) is a part of the axis, as are the arm and axis of the roller (25). Half of the metal of the axis under the closing-spring is cut away to give the spring greater scope. With the exception of the extractor, this completes the recoiling part of the mechanism.

21. The hand-lever (2) is used for opening or closing the breech when desired, as in first loading, but it has no part in the operation when working semi-automatically. The hub (32b) fits over the end of the axis and its spring-key (33) engages a groove in the end. When not in use, the handle (34) rests in a shallow groove in the outside of the side-box.

22. The closing-spring (41), a very powerful flat spring, rests as shown with its elbow in a recess in the rear end of the side-box, its upper branch in a notch in the top and its lower arm pressing on the friction roller (25), by which it exerts its force on the action-lever through the axis (8).

23. The thrust-pawl (28), pivoted to the sleeve, is pressed downward against the tumbler by its spring (30).

24. The extractor (21) works on its pin (23), inserted from the left side, and has two branches or arms; each arm has a flat spring on its outside which bears strongly against the curtain of the gun and prevents the extractor from moving too easily; there is the usual claw on each arm for engaging the cartridge-case, and also a lug (21b) by which the extractor holds the block down, when the breech is open. The tail of the extractor (21a) enters the recess in the block during the first portion of the downward motion and is forced forward, at first slowly and then abruptly, by the corner of the block which is shown in section near the lug (21b). The hub of the action-lever is cut away at (5b) to permit sufficient throw of the extractor.

25. The firing mechanism comprises the *firing-pin* (9), *firing-spring* (12), *cocking-bar* (13), *sear and spring* (18) and (19), *safety-sear* (15), *trigger* (37), *trigger-lever* (20), and *trigger-pull* (39).

26. The heavy cylindrical firing-pin (9), with a separate firing-point screwed into the end, works back and forth in a recess in the block. There is a vertical slot (9a) through which passes the cocking-bar (13), pivoted at (14), the movements of which accompany the motion of the pin in firing as well as in cocking; the cocking-bar has points of engagement for the sears at (13a) and (13b).

27. The heavy flat firing-spring (12) is held in place by its own tension pressing its rear arm into a shallow recess in the covering plate (2); the other arm presses against the rear end of the firing-pin. The safety-sear (15)—the purpose of which is to hold the mechanism at full-cock until the breech is fully closed—is pivoted at (16) and its rear arm is pressed upward against (13a) by the small spiral spring (17).

28. The *trigger-sear* (18) is held in the block by the trigger-lever shaft (20a) with which it turns; its arm is forced upward by the flat sear-spring (19), which really forms one part with the sear and is assembled with it. The shaft (20a)—square in section only where it passes through the sear—rests in bearings in each side of the block; the trigger-lever (20) projects forward from its right end.

29. *The trigger* (37), a bell-crank lever, is a non-recoiling part of the mechanism, pivoted in the side-box on the axis (38); its upper arm bears on the trigger-lever and the lower one is secured to the trigger-pull (39). The latter is assembled with, and has fore-and-aft motion in, the pistol-grip (40), which is a part of the gate of the sleeve; the spiral spring (39a) exerts its force to press the upper arm of the trigger upward, away from the trigger-lever. When the switch (45), (which is found in two forms), is thrown into action, it holds the trigger downward so that the trigger-sear is tripped and the gun fired automatically, on the completion of the breech closure.

30. The operation of the mechanism is as follows: Suppose the gun has just been fired and that all the parts are in the position shown in the plates:

31. Opening.—On firing, the gun and the recoiling parts of the mechanism move to the rear, drawing the piston-rod out, which checks the recoil—the right end of the axis (8) travels in a slot in the side-box. As soon as the tumbler (43) has moved rearward sufficiently, the thrust-pawl snaps down and lies in line with the notch on the forward side of the tumbler. During the counter-recoil, the tumbler strikes the pawl and is forced backward until the notch in its edge becomes so inclined that the pawl disengages itself by slipping up; the axis, with all its parts, is thus revolved by the tumbler, which raises the roller and thus compresses the closing-spring. The action-lever (5) turning with its axis, brings the block down by the action of its pin (6) in the slot (1c); the extractor arms are forced to the rear, at first slowly, then quickly but with less power, until the empty case is ejected and the lugs (21b) are in line with and above the recesses (1d). When the thrust-pawl slips off the tumbler, the closing-spring raises the block slightly until it is arrested by the extractor-lugs, and the breech is held open, ready for loading.

32. As the pin (6) swings rearward, it presses back the cocking arm and with it the firing-pin, compressing the firing-spring, until—at the moment the opening is completed—both the safety-sear (15) and the trigger-sear (18), forced upward by their springs, engage the lugs (13a) and (13b) respectively, and hold the mechanism in the cocked position.

33. Closing.—If the cartridge now be sent home sharply, its rim strikes the extractor-claws, forces them forward and frees the block by disengaging the lugs (21b). The closing-spring, which by pressing the roller downward has been exerting a strong force to revolve the axis (8) with the hands of a watch, now shoots the block upward by the action of the lever-pin (6) in the slot; as the tumbler turns upright again the thrust-pawl rides up on its end.

34. When the lever-pin nears the end of its travel, it strikes the safety-sear and disengages it from the cocking-bar. The trigger is again in contact with its lever (20); when the trigger-pull is pressed to the rear by the gun-pointer's finger, it disengages the trigger-sear (18),—through the several intermediate parts,—and the firing-spring shoots pin and cocking-bar for-

ward and fires the gun,—whereupon the opening operation is repeated.

35. The hand-lever.—When the axis (8) recoils, it slips away from the hub of the *hand-lever,*—the spring-feather (33) and the slot in the end of the axis, in which it lies, being horizontal at the time. Before the axis, brought back by the counter-recoil, again touches the hub, it has been revolved and the beveled edge on its end causes the feather (33) to ride up out of engagement, where it is ready to snap into place again when the axis revolves to the closed position. Thus, while the lever is at all times in place ready for use, it has no part in the semi-automatic operation during which it rests immovable in its retaining notch on the side-box cover.

36. If the switch (45) be thrown "in," or the trigger-pull be held back by the gun-pointer, the trigger-sear and the safety-sear will be tripped at the same time and the gun will fire at the moment of closing. In addition to this, an automatic loading device, or hopper feed, has been designed, which when fitted really makes the gun *automatic* in all operations.

37. About the same causes will produce failures in ejecting the empty case, opening or closing, as are given for the Hotchkiss system. The parts are all very strong and are not liable to give trouble.

CHAPTER XXIII.

AUTOMATIC AND MACHINE GUNS.

1. An automatic gun is one in which the explosion of each cartridge successively and continuously operates the mechanism to eject the empty case and to load and fire another cartridge so long as ammunition is properly supplied,—no manual effort, other than holding back the trigger, being necessary after the gun is once loaded and the first shot fired. Automatic guns are usually single-barreled and provision is made against overheating during sustained firing. In the two systems employed in the U. S. Navy the ammunition is fed to the gun in belts. The automatic guns used by the navy are:

(1) The *Maxim-Nordenfelt* 37 mm., or 1-pounder, which is properly called an automatic *rapid-firing* gun. A description, with instructions on its care and manipulation, has been published by the Bureau of Ordnance.

(2) The *Colt,* of rifle caliber only. Those first constructed were of 6 mm. caliber; the later ones use the 30-caliber service rifle ammunition and the others are being converted to the same size, but will have a few minor differences in the working parts.

2. A machine gun is one in which the continuous operation of the mechanism by means of a crank or lever, worked by hand or by motive power, ejects the empty cases and loads and fires continuously as long as ammunition is supplied and the mechanism kept in operation. Thus in a machine gun, the energy which works the mechanism comes from an external source and in an automatic gun, part of the force of explosion of one cartridge loads and fires the next. A machine gun—the term is generally applied to guns of small-arm caliber only—has usually more than one barrel. Those in use in the U. S. navy are:

(1) The *Hotchkiss revolving cannon* of 37, 47 and 53 mm. caliber. The gun has five barrels which revolve about a common

axis and fire successively; few of these guns are now in use and none have been built for years.

(2) The *Gatling*, a ten-barreled gun, one of the first really successful machine guns invented, was formerly supplied as a 45-caliber gun; those now being furnished use the service rifle—caliber .30—ammunition.

3. Machine guns of small caliber have been used with good effect in actions between ships and shore fortifications (war between Chili and Peru, and the British bombardment of Alexandria), by driving the crews of exposed guns to cover. Boarding, a prominent feature of actions held less than a century ago, is no longer thought of, and it is doubtful if ships in the future will ever approach each other, or shore batteries, sufficiently to permit the use of such guns—at least not until the latter stages of an action, when all exposed guns will probably have been destroyed. However, most ships carry a few automatic or machine guns, mounted in exposed places—often in the tops—which have large arcs of train. Considerable reliance is placed upon them, particularly on those firing explosive shell of 1-pound weight or upward, in repelling torpedo attack. Guns of these types are extremely valuable to small craft that closely approach the shore, or operate in rivers, in warfare with savage or semi-civilized peoples; rifle-calibered guns have been very effective in actions afloat and ashore in the Philippines.

The Colt Automatic Gun (Plate I).

(Fig. 1 is a plan, gas-lever back; Fig. 2 is part in section and part in profile, gas-lever closed; Fig. 3 gives a view of the working parts, the side plates having been removed, with the gas-lever back.)

4. The Colt automatic gun is one in which the force required to perform the several motions of firing, extracting, and loading is derived from the powder gases, a portion of those from each discharge passing through a small vent in the bore near the muzzle and actuating the mechanism of the gun through the medium of a lever or pendulum. Thus, a feed-belt being entered in position, the gun loaded and the trigger pulled, the energy de-

rived from the explosion of the first cartridge sets in motion the mechanism which extracts and ejects the empty case, advances the feed-belt one pocket, withdraws a cartridge from the belt, places it in the chamber, closes the bolt on it and fires it.

5. *The gun consists of a single barrel* (92) attached to a frame or receiver (88), the mechanism being contained in the latter and cased in by the side (89 and 90) and bottom (91) plates. The barrel is made much heavier than the barrel of the small arm, to reduce vibration, retard heating and expedite cooling; the greater mass of the barrel causes it to heat more slowly, while its greater surface facilitates radiation.

6. Automatic mechanism.—Fig. 2, Plate I, shows the gun closed and with empty chamber; in this state, the vent in the bore is closed by the piston (35), which fits into a recess in the gas-cylinder (27); the latter embraces the barrel snugly, but is not secured to it by any fixed connection; the gas-cylinder pin (28) joins the gas-cylinder and gas-cylinder bracket (33) while the front side-plate screw (55) passes through both and through both side plates.

7. The piston (35) is pivoted to the gas-lever (29), by the gas-lever piston-pin (36), and has enough motion about this center to allow of its moving freely in and out of the recess in the gas-cylinder, when the gas-lever swings about its pivot at (34).

8. It should be noted that no parts are rigidly connected with the barrel except the receiver; consequently, when the barrel is heated by rapid firing, its expansion does not affect the relations of the other parts; it slides through the gas-cylinder and bracket, which are made as light as possible so that they will expand more quickly than the barrel and allow the latter to move through them. The aperture in the gas-cylinder is made of such a size and is so located with reference to the gas-vent, that the latter is not masked by the expansion of the barrel. The gas-cylinder and bracket, being tied together, expand in unison, while the somewhat loose expansion of the gas-lever does not affect its action, as the freedom of the piston is sufficient to cause it always to enter the aperture in the cylinder.

9. The gas-lever being pivoted as stated, and moving about the gas-lever bracket-pin (34), is, when at rest, held as in the cut

by the action of two springs (37 and 38), which are known as the retracting springs and are contained in the tubes (39 and 40). These springs are kept in partial compression by the followers (41 and 42), and the pressure exerted by them is communicated through the retracting connection (45), the short links (49 and 50), and the long link (47), to the crank-arm of the gas-lever, thus keeping the latter firmly in the closed position.

10. If, now, the gas-lever be moved about its pivot (34), its motion takes place in the vertical plane passing through the axis of the bore and the system of bell-crank lever, links, connecting rod, and follower compresses the retracting springs. When the lever has been swung down until it strikes the forward end of the bottom plate (91), it can move no further, and, if released, will be thrown back to the closed position by the action of the springs as above described. The retracting-spring tubes are tenoned into the gas-lever bracket (33), as shown in the cut; their rear ends are free and open.

11. When the gas-lever is swung down, the rod (31), called the gas-lever connection—being pivoted to the gas-lever at the point (32) and the slide (86) at the point (87)—transmits the motion of the gas-lever to the slide, which latter is constrained to move fore and aft in grooves in the interior walls of the receiver, and is further guided by the rectangular ends of the pin (87), which move in slots in the two side-plates.

12. On the right side of the slide, near its forward end, are two projecting lugs, shown in dotted lines in the cut; as the slide moves to the rear, actuated by the connection (31), the forward one of these lugs strikes the free end of the feed-lever (66) which pivots about its screw (67); a stud on the face of this lever, moving in a slot in the ratchet-lever (71), causes the latter to swing about its screw (72); the free end of the ratchet-lever rises and the pawl (73) is pressed in against the pawl-spring (74), the face of the pawl being beveled so as to slide along the face of the feed-wheel (61).

13. The front end of the latter consists of six radial teeth of peculiar form, and as the ratchet-lever rises, the pawl, having reached the upper and flat side of a tooth, springs out and rests on the tooth. The slide now having reached its extreme rear

position, on its return motion the rearmost of the two lugs strikes the feed-lever and the ratchet-lever is forced down, the projecting pawl engaging the tooth of the feed-wheel and turning the latter to the right.

14. A spring-dog (63), pivoting about a screw (64) in the bottom plate, is of such shape that it permits of the revolution of the feed-wheel to the right, but prevents motion in the other direction. A device is provided for permitting the feed-wheel to be turned backward when desired; it consists of a throw-off (68), (not well shown in the plate), operated by a knurled screw-head (70) on the right side-plate, just below the belt exit; if this screw-head be pushed forward, the throw-off draws the dog out of engagement with the feed-wheel, which can then be rotated backward, thus allowing of the removal of a partially empty belt.

15. The belt-guide (59) prevents the "bunching" of the belt into the channel between the two sides of the slide. It is secured to the receiver by the screw (60) and by a tenon near its rear end.

16. The cartridge-extractor (82) is pivoted to the slide at (83); the rearward motion of the slide causes this extractor to draw a cartridge from the feed-belt and to deposit it on the carrier (21), which, at (22), is pivoted to the receiver. On the same pivot with the cartridge-extractor is borne a cartridge-guide (80), and when the slide is in its forward position this guide engages the cartridge, in connection with the cartridge-extractor, and holds it in a central position.

17. The function of the carrier is to receive cartridges from the extractor, raise and present them in front of the breech-bolt (13) for loading into the chamber. The slide in its rearward motion strikes the carrier-dog (23), which pivots about its pin (24); the first effect is to compress the spring (25); when the slide has moved so far to the rear that the extractor (82) has withdrawn the cartridge entirely from the belt, the dog-spring has been so far compressed that the slide passes over the dog, causing only a slight depression of the rear end of the carrier, and a corresponding elevation of the front or free end. When the cam surface of the slide-lug (seen just below the number 14, Plate I) has passed over the carrier-dog, the latter is freed and is sprung back to its normal position, that shown in the cut. The

return motion of the slide now begins, the slide-lug strikes the rear face of the dog and sharply raises the front end of the carrier, presenting the cartridge in front of the breech-bolt; passing over the dog, the slide cam-lug strikes the flat upper surface of the carrier forward of its pivot and forces it down into horizontal position, ready to receive a second cartridge.

18. Bolt mechanism.—Passing next to the consideration of the breech-bolt (13), it is seen that it is cylindrical in form, with a central guide-rib on its lower side at the rear, which depends into a slot in the rear end of the slide, and is there secured by the bolt-pin (14). This pin, instead of rigidly pivoting the bolt, passes through a cam-shaped slot, so that a certain amount of motion of the bolt is allowed, both vertically and fore and aft, about the pin.

19. Starting, as before, with the gas-lever up and slide in forward position, the breech-bolt is seen to be entirely closed, with its rear face lying against the recoil shoulders in the frame; the first effect of the rearward motion of the slide is to cause the rear end of the bolt to rise, owing to the action of the pin in the cam-slot; this clears it from the recoil shoulders, and it then moves directly to the rear with the slide, leaving the way clear for a cartridge to be fed up by the carrier. On the forward motion of the slide, the reverse operation takes place, the bolt first moving forward horizontally, pushing a cartridge before it, and finally canting into the locking position.

20. The bolt carries the firing-pin (18) and extractor (15); the former is held to the rear by the spiral-spring (19), its rear end projecting from the bolt, and is driven forward against the primer by the blow of the hammer (6) against its projecting end, when the latter is released by the trigger and sear. The extractor (15) is carried in a slot on the right side of the bolt and grasps the head of the cartridge as it is forced up by the carrier; it has a slight rotary motion about the vertical pin (17), a small spiral-spring under its rear end holding the nib so as to engage the rim of the cartridge.

21. The ejector, not shown in the plate, is located in a groove in the left side of the receiver, in such a position that a projecting lug on its inner side is struck by the head of the case when

the latter is clear of the chamber; the blow releasing the case from the extractor and throwing it violently out, through the opening provided for the purpose in the right side of the frame.

22. The hammer (6), firing-spring (7), sear (10), sear-spring (11), trigger (8), and trigger-spring (9) are carried in the handle (1). When the hammer is free from the trigger and sear, it lies with its head against the rear end of the bolt and firing-pin; when the bolt moves to the rear with the slide the hammer is forced back into the handle, compressing the spring, until the notch around its head is engaged by the trigger and sear-nibs; it is then held in the position shown in Fig. 3 until released by the trigger and sear.

23. As both trigger and sear engage the hammer, both must release it before it can fly forward; the necessity of both trigger and sear is plain when it is considered that in automatic firing the trigger is held back continuously, the sear alone holding the hammer until the moment of firing. For releasing the sear automatically the following device is employed:

24. An oscillating lever or tripper lies in a slot on the left side of the frame, being pivoted at its middle point, and having the lug end forward. With the slide in its forward position, the pin on the forward end of the tripper lies on top of the slide, just forward of the number (14) in Fig. 2; this end being thus elevated, the rear end is correspondingly depressed and the pin at that end forces down the toe of the sear, out of engagement with the hammer; this leaves the hammer held only by the trigger, and upon this being pulled, the hammer flies forward, discharging the gun. If, now, the slide be moved to the rear, the cam on its left upper side allows the pin on the forward end of the tripper to drop, and the pressure of the sear-spring, meeting no longer with resistance, forces the sear up against the hammer, raises the after end of the oscillating-lever and depresses the forward end. The rearward motion of the slide continuing, the bolt forces back the hammer, compresses the mainspring, and the cocking is completed just before the end of the rearward motion, the hammer being held by both the sear and trigger. The slide then moving forward, the release of the sear takes place, as above explained.

25. In automatic firing, the hammer is released when the pin

on the forward end of the tripper reaches the top of the cam cut on the slide, which extends from (14) to near (60) (see Fig. 2).

26. An inspection of Fig. 3 will show a channel in the upper part of the receiver, connecting the hammer casing with the chamber of the gun; a small brass tube forms the connection as shown; the rapid alternating motion of the hammer in its casing forces a jet of air through this tube into the chamber of the gun, which is found to be practically serviceable as a cooling agent and for cleaning the chamber of grains of unburnt powder.

27. The safety-latch (58) has a thumb-piece on the right side of the outside of the receiver and a lever, at right angles to it, inside; when the thumb-piece is pushed forward, the lever inside rises in front of the hammer and restrains it if both sear and trigger are released; this is the "safe" position; with thumb-piece of safety-latch pushed to the rear, the lever lies below the face of the hammer and does not prevent its moving forward when released.

28. Sights.—The gun is sighted up to 2000 yards with plain open sights much like those of the service rifle; there is no wind or drift connection. The sights are marked for single shots,—in automatic firing the shots will fly high—about one foot in 200 yards.

29. The gun, as furnished to ships, is seated in a cradle which in turn rests in a saddle with a pivot; there is a suitable cradle clamp. It may be mounted on a tripod, a field carriage, a 1-pounder pivot-stand (with an adapter), or in a permanent socket on the rail. The gun should not, except in emergencies, be left mounted where exposed to the weather. The canvas feed-belts, containing 250 cartridges each, are laid down "clear for running" in a box attached to the left side of the mount. The cartridges must be inserted in the belt to exactly the proper distance, to prevent their jamming in the gun, and this is best done by a belt-loading machine.

Operation of the Gun.

30. The outer end of the feed-belt has a brass tip which is entered in the cartridge-shaped aperture in the left side-plate and

drawn through the belt-exit,—the rectangular hole in the right side-plate,—as far as it can be drawn. The feed-wheel (61), having six teeth at each end, forms six cradles, one of which is always at the top, so that a cartridge lying in it, is in the middle line of the gun and horizontal. The first cartridge of the belt is stopped in this position, and the belt can be drawn no farther, on account of the rear end of the cartridge bringing up against the feed-roll wall, which is seen in the plate just in rear of the feed-wheel; the cartridge cannot cant in the cradle, since the bullet is held by the bullet-guide, which is secured to the inside of the left side-plate just forward of the cartridge-shaped opening.

31. The belt being thus entered, and a cartridge in the feed wheel, the gas-lever is swung by hand through its full arc to the rear and released, when it flies back into the closed position, under the tension of the retracting springs. The backward swing of the lever moves the slide to the rear, as already explained.

32. In the first three-eighths of an inch of motion of the slide, three operations are accomplished: the head of the first cartridge is gripped by the cartridge-extractor and by the cartridge-guides; the bolt is unlocked by the raising of its rear end; and the sear released by the tripper, rises against the hammer.

33. In the next one and one-half inches of motion the main-spring is compressed; at this point the forward lug on the right edge of the slide strikes the feed-lever and begins to move it to the rear. After another seven-eighths inch, the slide strikes the carrier-dog, and at four inches, the cocking is completed, the feed-lever is in its extreme position, the cartridge is raised slightly out of the extractor, the trigger and sear snap over the head of the hammer, and the bolt is fully drawn back.

34. The forward swing of the gas-lever draws the slide forward, the first effect being to throw up the front end of the carrier,—the lug on the under side of the slide striking the carrier dog as before explained. This raises the cartridge diagonally and stops it with the bullet pointing into the chamber and the head presented in front of the bolt which is again moving forward; the slide-lug, having passed over the dog, strikes the upper surface of the carrier and begins to push it down, and at the

same time the bolt-face strikes the cartridge and pushes it into the chamber, the bullet being guided by the *chamber-guide* (77).

35. Shortly afterward the rear feed-lug strikes the feed-lever and pushes it over to its forward position, turning the feed-wheel one-sixth of a turn to the right and presenting another cartridge to the extractor; the last operations are the locking of the bolt by the depression of its rear end, and the bearing of the sear off the hammer by the forward pin of the tripper riding up the incline at the rear end of the cut on the slide.

36. The gun is now loaded, a cartridge in the chamber; another one ready to be gripped by the cartridge-extractor; the main-spring is fully compressed, and the hammer restrained by the trigger alone.

37. If, now, the trigger be pulled and released, the cartridge in the chamber is discharged and all the operations above described are repeated, the gas-lever being thrown back by the pressure of the gas through the vent and returned to position by the retracting-springs. The empty case is also extracted and ejected as heretofore explained. The gun is thus fired, the empty case ejected, another cartridge loaded into the chamber, a third presented to the cartridge-extractor, and the gun cocked, all by simply pulling the trigger and releasing it.

38. If, now, instead of being released after pulling, the trigger be held back, the operations above described will be performed in precisely the same way up to that point, in the forward swing of the lever and forward motion of the slide, where the tripper forces the sear off the hammer; when this stage of the motion is reached, the trigger no longer restraining the hammer, and the sear being forced off by the tripper, the hammer is released, flies forward, and discharges the gun; the same operations are then repeated, and automatic action is obtained as long as the trigger is held back and ammunition is furnished by the belt.

39. The belt is drawn through by the feed-wheel and is dropped out on the right side of the gun when empty; if it be desired to remove a partially empty belt, it can be drawn out to the left on pushing forward the knurled button on the right side of the gun, which allows the feed-wheel to be rotated backward.

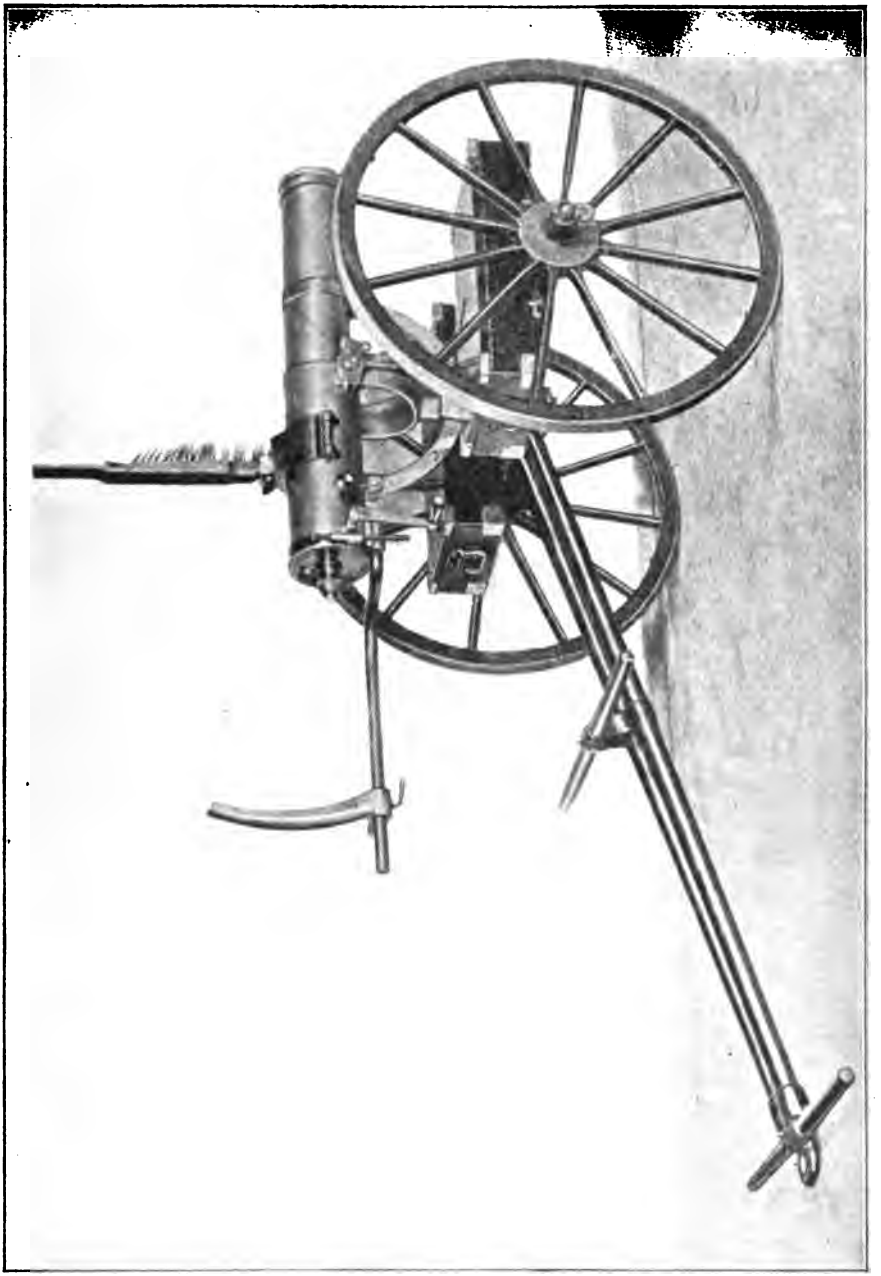
The Gatling Gun, Mark II, Caliber .30.

(See Plates II, III, IV, V, and VI.)

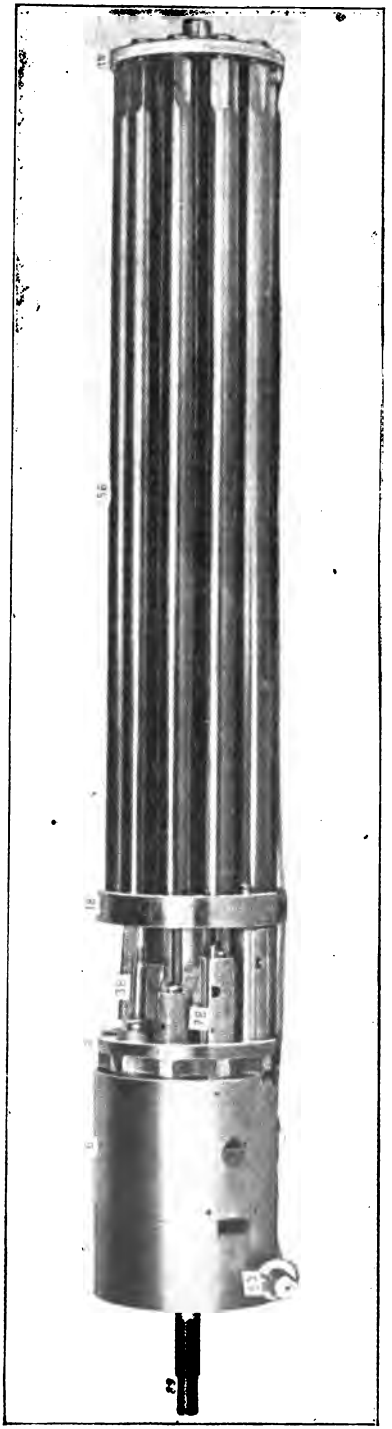
40. The Gatling gun is a machine gun in which the operations of entering the cartridge in the chamber, firing the cartridge and ejecting the empty shell are all performed mechanically by the simple turning of a crank. In the navy type of the Gatling gun all the mechanism and the barrels are encased in a brass casing. The ammunition for the last design is the same as for the .30-caliber Colt and the .30-caliber rifle. The sight is of the plain bar type, graduated to 2000 yards.

41. The casing (Plate II) is a hollow brass cylinder open at both ends. It is bored to two diameters, the forward diameters corresponding to the diameters of the barrels plates (18 and 19, Plate III), and the rear diameter corresponding to the diameter of the cam-cylinder (6) and diaphragm (5) (Plate III). On the front end of the casing is screwed the front-bearing (21, Plate VI), which receives the forward end of the main-shaft (89) and furnishes it with a bearing. There is a lug on the forward end of the casing for the front sight, lugs on the rear end for the hopper hinge-pin (37) and for the crank-shaft bearing, and lugs on the under side for the arc and pointing-lever. There is a key-way cut in the casing on its inner surface, after end, for the cam-cylinder key (7, Plate V). This key, when in place, locks the cam-cylinder (6) and diaphragm (5) against rotary movement in the casing. The rear end of the casing is threaded to receive the cascabel-plate (16), which is also threaded; these threads are half cut away in the interrupted-screw fashion.

42. Revolving parts.—Referring now to Plate III, it will be seen that the barrels (56), ten in number, are symmetrically located about the main shaft; the front ends of the barrels resting in the front barrel-plate (19) and the rear ends being screwed into the rear barrel-plate (18). Both barrel-plates are keyed to the main shaft so that they must revolve with it, carrying with them the barrels. The hexagonal shape of the barrels, immediately in rear of the front barrel-plate, is for receiving a wrench when screwing them home.



GATLING GUN, MOUNTED ON NAVY FIELD-CARRIAGE, WITH THE DIRECTING-BAR, SHOULDER-REST, CRANK, AND FEED GUIDE-WAY SHIPPED.



GATLING GUN, WITH CASING REMOVED.

43. On the after face of the rear barrel-plate is a hub on which the carrier-block (38) assembles. The carrier-block is still further held in place by a longitudinal dowel-pin (39, Plate VI), the forward end of which protrudes into the rear barrel-plate and the after end of which protrudes into the lock-cylinder disk (2). The carrier-block is best seen in Plate VI; the grooves shown are guideways for the locks and for the cartridges.

44. The lock-cylinder disk (2) and body (3), assembled as one part, are axially bored to fit the main shaft and are keyed thereto immediately in rear and abutting against the carrier-block; thus the lock-cylinder body is the rearmost piece which revolves with the main shaft, barrels, etc. The rear guide-nut (9) screws on the main shaft in rear of the lock-cylinder and prevents its longitudinal displacement. The lock-cylinder has ten guide grooves in which the locks travel through the ten holes in the disk which have the same profiles as have the locks. These guide grooves are continued on the surface of the carrier-block (38), and are there sloped away at the top to form pockets which take up and bear the cartridges. In Plate III, the lock-cylinder is concealed by the cam-cylinder (6), but the disk (2) is shown just in rear of the carrier-block; the locks (78) may be seen protruding through the disk—a cartridge is shown in front of one at the moment of being pushed into the barrel. It will be noted that the main shaft, ten barrels, two barrel-plates, carrier-block, and lock-cylinder are all rigidly locked together, none having any motion independent of the others, and are revolved with the hands of a clock by a crank.

45. The locks (7), ten in number, are best seen in Plate IV. They are of irregular section and are provided with T-shaped guide-ribs which travel in the grooves of the lock-cylinder and carrier-block; there is a radially projecting lug on the rear end of each which engages the cam of the cam-cylinder (see Plate IV), by which the locks are moved back and forth. The outer side of the lock is slotted nearly its whole length to receive a straight extractor which, to obtain elasticity, is secured only at its rear end. The center of the lock is bored out to receive the spiral firing-spring and the straight firing-pin; on the rear end of the latter is formed a knob which engages the groove of the

cocking-switch. A loose sleeve around the front end of the firing-pin has two arms which project forward enough to strike the front shoulder of the lock when the pin goes forward and thus causes it to rebound slightly after striking the primer.

46. The cam-cylinder (7), (Plates III and IV), surrounds the lock-cylinder, abutting against the rear face of its disk, and is keyed to the casing so that it cannot revolve. The cylinder has a recoil-plate (14) (Plate V) screwed to its front lower edge, against which the rear ends of the locks abut, and are supported, during firing. On the inner surface of the cylinder a spiral cam is cut which operates the locks by the lugs on their rear ends. The cocking switch (63) is held in a longitudinal dovetailed slot in the cam-cylinder; it is held forward by a light spiral spring, but may be moved rearward by turning a milled head, called the cocking-switch knob, on the right-hand side of the gun (see Plate II); when moved to the rear the switch is out of action and will not cock the locks.

47. Diaphragm.—Immediately in rear of the cam-cylinder, and abutting against its after end, is the *diaphragm* (5), (Plates III and V), keyed to the casing with the same key as the cam-cylinder. It is bored axially for the rear bearing of the main shaft and transversely, on its lower side, for the crank-shaft. In its upper left-hand portion is a sleeve for the lock-plug (44), the use of which will be explained.

48. The main-shaft worm-wheel (12, Plate V) assembles on the main shaft, to which it is keyed immediately in rear of the diaphragm, and engages the crank-shaft worm-wheel (13), which is carried by and keyed to the crank-shaft (53), immediately below the main shaft.

49. The cascabel-plate (16, Plate V), assembling next in rear of the diaphragm, has a lug for the rear sight; it is threaded to correspond with the threads on the rear end of the casing. On its upper inner surface is a small steel stop-plate, which, when the cascabel-plate is screwed in position, abuts against a small screw in the casing and thus assures the correct position of the cascabel-plate which carries the rear sight.

50. The adjusting-knob collar (51, Plate VI), adjusting-knob collar-spring (52), and adjusting-knob (50) are assembled on

the main shaft in rear of the cascabel-plate,—the adjusting-knob screwing on. The collar is keyed to the main shaft and revolves with it; its forward side abuts against the cascabel-plate, while the adjusting-knob abuts against its after side; the spring serves to lock the adjusting-knob in position on the shaft. The use of these parts is to regulate the "breeching up." The adjusting-knob is screwed on to the main shaft until it abuts against the collar with a sufficiently firm bearing; the more it is "set up" the more the barrels will be drawn aft, or the less distance there will be between the forward end of the lock in its firing position and the after end of the barrel. If it is screwed up too tight there will not be room for the cartridge head, or, if there is room, there will be so much friction that the gun will turn hard. If the adjusting-knob is not screwed up far enough, the cartridge will not be fully entered in the chamber, and, when firing, the cartridge case may bulge under the rim, or even burst, and thus cause a jam.

51. The hopper (23, Plate VI) is hinged to the casing and is slotted to receive the feed-guide-way, and to provide a passage-way for the ammunition into the gun. The function of the hopper-plow (24) is to assist in ejecting the empty cases. The hopper-feed walls (30 and 33) provide bearings for the hopper-feed wheel (35) and serve to guide the cartridges into the grooves of the carrier-block.

52. The feed-guide (constructed on the Bruce Feed System), shown in place in Plate II, contains two channels for the cartridge rims and ships over the opening in the hopper. The cartridges are inserted from the top, travel downward by gravity, and drop off one by one to the grooves of the carrier-block, through the medium of the feed-wheel.

Operation of the Mechanism (see Fig. 1).

53. The gun being assembled, directing-bar, crank, and feed-guide shipped, the cocking-switch knob should be turned with the arrow pointing forward to put the switch in action, if this has not already been done. The ammunition is entered in the feed-guide directly from the pasteboard boxes in which it is furnished;

the two channels in the feed-guide engage the rims of the two rows of cartridges in the box, the box is pulled off and the cartridges drop down in place until the first one rests on the hopper-feed wheel, and the gun is ready for firing. If the crank is then turned, the force of gravity will cause the hopper-feed wheel to turn so as to deposit one cartridge in each groove of the carrier-block. The position of the locks in the grooves of the carrier-

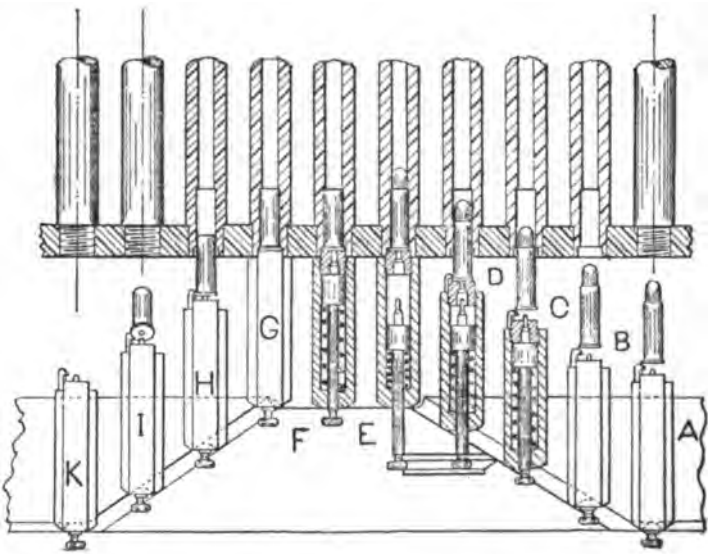
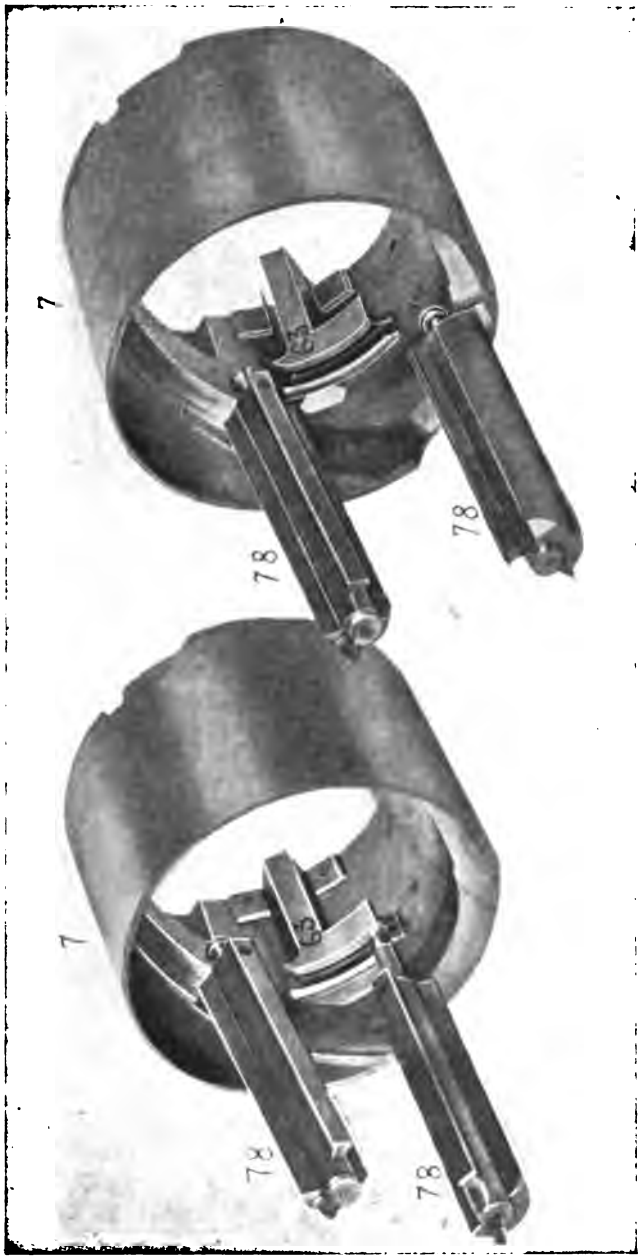


FIG. 1. ART. 53.

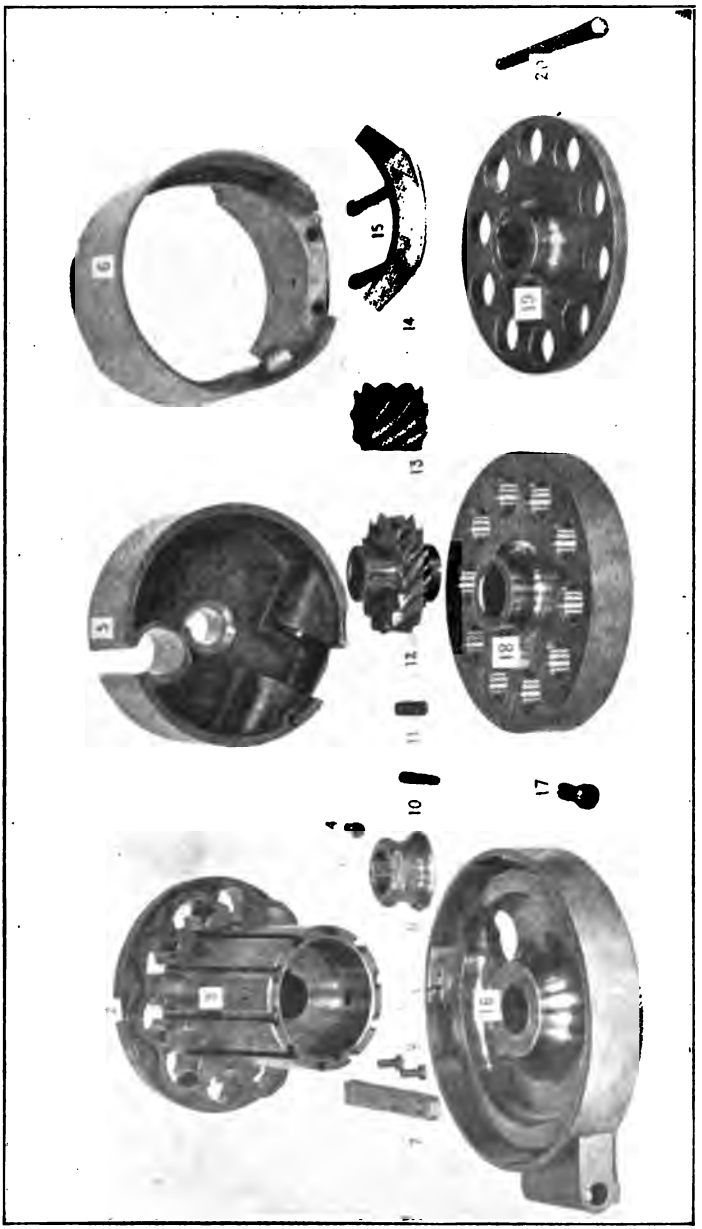
DEVELOPMENT OF CAM-CYLINDER FOR GATLING GUN.

Showing operation of the locks diagrammatically.

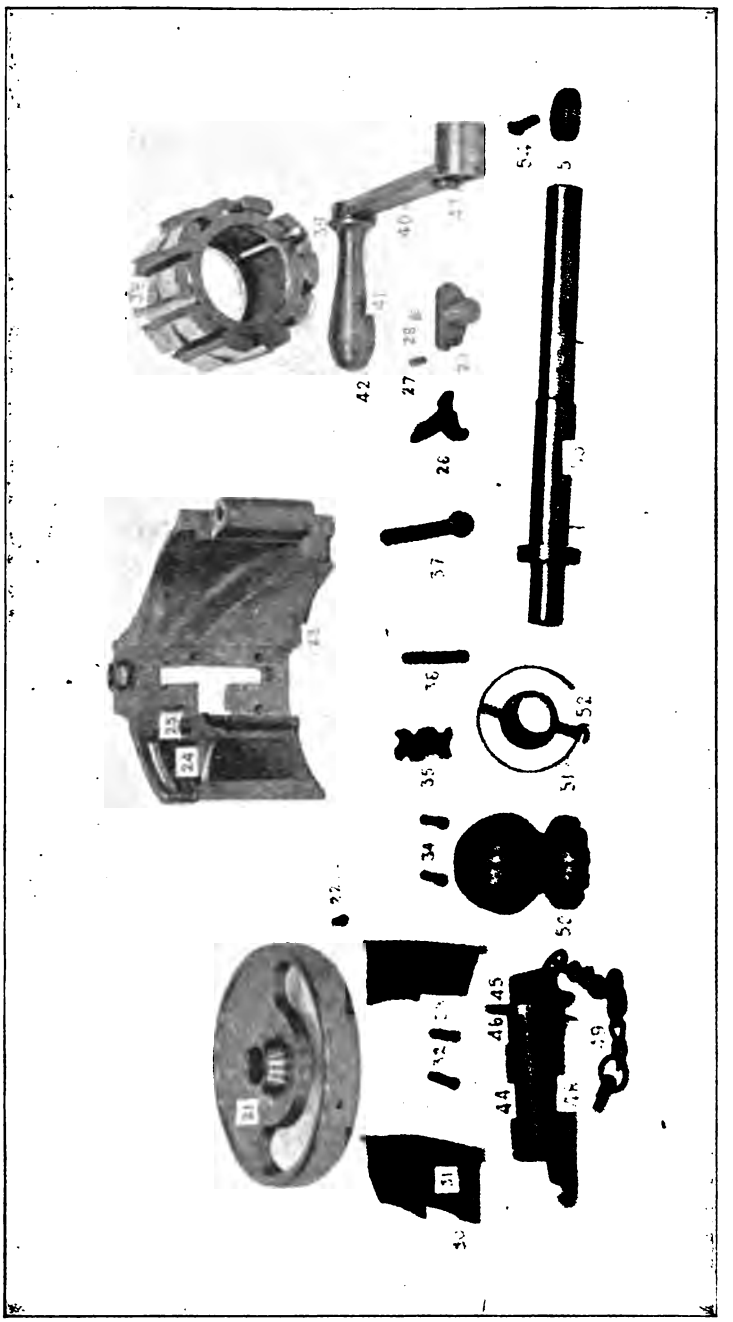
block and lock-cylinder are regulated by the cam of the cam-cylinder, so that the locks in their uppermost position are also in their rearmost position; the cartridges are deposited in the grooves of the carrier-block in front of the locks. As the crank is turned, the lock-cylinder and carrier-block revolve, carrying with them the locks and cartridges. The cam-lugs on the locks engaging the cam on the inner surface of the cylinder,—which cylinder does not revolve,—causes the locks to move forward,



TWO VIEWS OF CAM-CYLINDER AND COCKING SWITCH.



PARTS OF GUN AND ACCESSORIES.



PARTS OF GUN AND ACCESSORIES.

each one pushing a cartridge in front of it. This forward motion of each lock continues until the cartridge in front of it is seated in the chamber, the extractor is cammed out over the cartridge head so as to grasp it, and the rear end of the lock presses against the recoil-plate, which is secured to the cam-cylinder as shown in Plate IV. As the lock travels forward, the cocking-switch (see Plate IV) grasps the knob of the firing-pin and holds the firing-pin to the rear while the lock travels forward, thus compressing the firing-spring. This compression of the firing-spring and holding to the rear of the firing-pin continues until the lock arrives in its forward position, at which point the cocking-switch groove ends and the knob of the firing-pin is released, whereupon the firing-pin flies forward and fires the cartridge in its barrel; the recoil of the lock being taken on the recoil-plate. It will be noted that the recoil-plate extends through a considerable arc, and that the lock remains in its forward position during revolution through the same arc; this provides against accident due to hangfires, as it will rarely occur that a hangfire will last long enough to permit the lock to travel off the recoil-plate. As soon as the lock leaves the plate, the cam-lug on the lock, which may be plainly seen in the left-hand figure of Plate IV, engages the rearward sloping portion of the cam. The revolution continuing, the lock travels to the rear and carries with it the empty cartridge case, which is held between the carrier-block, extractor, and casing, until the cartridge case is opposite the exit on the left side of the casing, when it is ejected.

54. The cocking-switch.—In Plate IV two different positions of the cocking-switch are shown. In the left-hand figure, the cocking-switch is shown in its forward position, so that as each lock travels down the cam in the direction contrary to the hands of a watch, the switch will grasp the knob of the firing-pin; it will be noted that the upper lock is approaching the cocking-switch and that the lower lock has its firing-pin about to be released by the switch. In the right-hand figure it will be seen that the cocking-switch is withdrawn to the rear so that the firing-pin knob of the upper lock does not engage it, and consequently this lock will not be cocked.

55. When the crank is shipped in rear, each revolution of the

crank causes one cartridge to be fired from each barrel. When the crank is shipped on the crank-shaft, 4 revolutions of the crank causes 23 cartridges to be fired from the barrels; the lower right-hand barrel is the firing barrel. When the gun is firing, the tendency of the recoil of the locks causes the cam-cylinder to be set back against the diaphragm, which is securely held against the cascabel-plate by the cascabel-plate screw (17).

56. Safety.—There is no safety arrangement in this gun so long as there are cartridges on the carrier-block. If the cocking-switch knob is turned with the arrow pointed aft and the crank is revolved, one cartridge will probably be fired and no others after that, but this switch is, however, not designed as a safety arrangement, but merely to enable the mechanism to be operated without cocking the locks.

57. *In case the cartridges stop feeding* into the carrier-block, it will probably be found that they are clogged just above the feed-wheel. To clear them, lift the cartridges slightly clear of the feed-wheel and allow them to fall back in position.

58. *In case of hang-fire,* the cartridge case may explode and cause a jam of the mechanism. This can nearly always be overcome by putting extra force on the crank and continuing to turn until the deformed case is ejected. It is not considered desirable to fire the gun at a rate exceeding 700 shots a minute.

59. The lock-plug (44), Plate VI, which has a hook on its front end, lies normally in a longitudinal slot through the upper left-hand side of the diaphragm and cascabel-plate (see Plate V); it projects to the rear enough to be easily handled. As the locks come in succession in line with the lock plug, they are engaged by the hook on its end and, being at that particular point disengaged from the cam-cylinder, may be pulled to the rear. Hence, to remove locks, turn crank until the qualifying mark on casing opposite rear end of barrel corresponds with a qualifying mark on rear barrel-plate; turn lock-plug to the right and draw it to the rear; this will withdraw one lock, through the lock-plug recess; the others may be withdrawn in the same manner.

60. Feed systems.—The first feed system devised consists of a long tin case of trapezoidal cross-section, containing 40 cartridges, lying one above the other, which fall by gravity directly

on the carrier-block. The cartridges do not always fall parallel to the guide-grooves and in very rapid firing do not fall quickly enough—hence jamming is likely to occur; besides, depending on gravity, it does not work regularly for different angles of elevation.

61. The Bruce feed, as described above, is also a gravity feed and open to the latter objection but it delivers its cartridges parallel to the barrels by passing them over the hopper feed-wheel (35).

62. The Accles feed consists of a large drum holding the cartridges by each end in spiral grooves in the heads; they are forced out of the spirals and into the gun by a revolving set of radial arms which is revolved inside the feed-drum by projections on the carrier-block.

63. The latest feed, like the *Accles,* is positive and certain in its action but is much lighter and less cumbersome. The cartridges are held in long tin strips by tongues punched out and bent around the cartridge body. These strips are fed through the hopper from left to right and the carrier block picks the cartridges off from the under side, bending the light tongues downward, as the feed strips go past.

CHAPTER XXIV.

FIELD ARTILLERY.

1. The field artillery, or guns carried by U. S. ships for operations on shore, is composed mainly of 3-inch field-pieces and machine or automatic guns of rifle caliber, on field carriages. All guns of these types often have, in addition to their field carriages, ordinary mounts on board ship on which they are mounted when not prepared for shore operations, and are included in the ship's battery.

2. The Colt and Gatling guns, described in the preceding chapter, are supplied with field carriages which permit elevation and a large arc of train without moving the trail. There being practically no recoil, brakes, spades, etc., are not necessary and the carriages are of simple construction and as light as possible, keeping in view the contingency of work over rough ground. A Gatling on its field carriage is shown in the preceding chapter; the carriage for Colt guns is very similar. Two ammunition-boxes on the carriage hold 1320 rounds, in the case of the Gatling, and 2000 rounds for the Colt gun. A limber or ammunition-carrier, consisting merely of a rack for holding the boxes, which is mounted on an axle, with wheels exactly like those of the carriage, is supplied with each Gatling field carriage. When the limber is used, the trail of the gun-carriage is hooked to its axle and the drag-ropes are attached to the trail of the limber; the latter has a total capacity of 12,000 rounds; if the spare-part and accessory-box is carried, a case containing 1000 rounds is removed from the limber to make room for it.

3. A tripod-mount is sometimes furnished with Colt guns, which is used both as a ship's mount and in shore operations; the saddle and pivot of the mount ship in a socket at the top of the tripod, the rear leg of which is longer than the others and bears a seat for the gun-pointer. The gun and tripod make a fair load

for two men and may be carried anywhere; thus mounted, it is practicable to use the gun over very rough country in which a wheeled carriage could not be used.

4. Carriages for 3-inch, 50 caliber, guns.—A limited number of carriages, designated *Mark III field carriages,* with limbers, have been constructed for the 3-inch, 50-caliber, gun. These carriages are necessarily large and cumbersome and are to be supplied only to the largest battleships and cruisers. The slide trunnions of the ship's mount rest in seats on a heavy trail which bears the elevating gear; the trail, which has no trail-wheel, is secured to an axle mounted on heavy wheels,—the rear end of the trail being hooked up to the limber, while on the march, and resting on the ground while firing. The piece has an arc of elevation of 15 degrees, with 10 degrees depression, when mounted in this manner, and train is effected wholly by moving the trail around. The recoil is absorbed by the carriage through the recoil cylinders in the usual manner and the carriage is restrained from running to the rear from the shock of recoil by a brake on each wheel and by wire cables running from strong pegs driven into the soil to two spring buffers, one at the axle and one at the lower end of the trail.

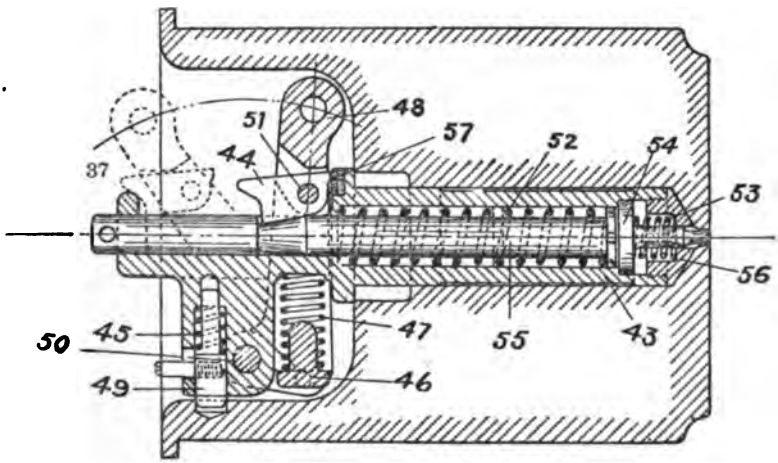
5. The limber holds ten ammunition-boxes, each containing four cartridges, and two more boxes are borne by the carriage; there are places on the carriage and limber for five or six men who are to be carried there principally for balancing purposes. The gun and field carriage weigh about 8000 pounds—too great a weight to be dragged by men—and the piece is designed to be drawn by horses hitched to the limber.

The 3-inch R. F. Field-Piece and Carriage.

6. The gun is a low-powered gun—as are most field-pieces when compared with ship's guns—23 calibers in length, weight about 400 pounds, forged from a single piece of steel; the muzzle velocity is fixed at 1250 f. s. The first 100 guns were mounted on the Mark I field carriage, and 60 recently completed have Mark II carriages; the guns themselves, however, are alike in all the principal features and are fitted with the Fletcher breech-

mechanism; the operating lever is bent down considerably to clear the firing-lock and there is a lock on its handle to prevent the block from jarring open.

7. The firing-lock is a special device, in which cocking the firing-pin, compressing the firing-spring and firing are all effected by a single pull of the firing-lanyard. The lock fitted to the first 100 guns is shown below, in its place in the breechblock; it consists of a case (43) that carries all the firing mechanism, and is



FIRING-LOCK. ART. 7.

readily put on or taken from the breech-plug, being held in its seat by a locking-bolt (49) and spring (45). It will be observed that the firing-point is not on the firing-pin, but is a part of the plunger (54), a separate piece that is struck by the firing-pin (55). A spring (53), surrounding the plunger, is supposed to keep the point within the nose of the plug ordinarily, and acts against the firing-spring which, when the pin is not cocked, has practically no compression,—so that, in closing the plug, no blow is given to the primer; the firing-pin and plunger are retained in the case by a cap (56) screwed in the front end. The cocking-lever (48) is ordinarily kept in the forward or uncocked position by a spiral spring (47), seated under the case, acting on a cradle

(46) that is pivoted between the jaws of the lever forward of the lever's (axis) pin (50); on the upper end is an eye for attaching the firing-lanyard. The cocking-pawl (44) is pivoted in the upper part of the cocking-lever, with its lower rear corner resting ordinarily against the cocking-shoulder of the firing-pin, and a toe on the upper rear end is provided, which is tripped by a toe (37) on the firing-case when the cocking-lever is brought to the rear enough to cock the firing-pin. The action is as follows: When the lanyard is pulled smoothly to the rear, the firing-pin is brought back by the cocking-pawl compressing the firing-spring until the pawl is lifted by the trip-toe on the rear end of the case, when the firing-pin flies forward, striking the plunger, the point of which strikes the primer of the cartridge.

8. Caution.—The lock, as at first designed, will permit of the gun being fired before the block is turned for locking, if the lanyard be pulled, which, of course, would lead to a serious result. One fatal accident (at least) has so happened. Hence great care should be taken to see that the firing lanyard is *clear* and is hanging so that it *will not be pulled in closing the breech* and that it is *not pulled before the word "ready"* is given by the man operating the mechanism.

9. In 1904, a device was designed by Lieutenant Graeme which, when fitted, removes this defect.

10. The later guns are being fitted with a modification of the lock described above; the new device is sometimes called the "Tasker" lock and in its main features is not greatly different. The firing-pin is held in the cocked position, main-spring slack, by a sear; when the cocking-lever, which is relatively much longer, is pulled to the rear, a sleeve which surrounds the firing-pin is forced forward, compressing the spring, until it trips the sear and the firing-pin flies forward and strikes the primer with its own point. When the firing-lanyard is released, the firing-spring, still slightly compressed, brings the entire mechanism to the rear to its former position, the cocking-lever straightens up and the sear re-engages the firing-pin. This lock as at first designed may also be pulled off before the breech is closed and, except that a longer pull on the lanyard is required, the same dangers of premature discharge exist. The same precautions, as given above,

must be taken in manipulating the lock, except when Lieutenant Graeme's device has been fitted. This type of firing-lock is, of course, only applicable to guns used on shore, where there is no movement of the gun platform, and where, consequently, it is not important to minimize the interval from the pull on the lanyard to the explosion of the charge.

11. The Mark I field carriage (see Plates I and II).—In this mount the sleeve combines the functions of sleeve and recoil-cylinder and the elevating-arc is formed on a projection on its underside. The *gun-body* where it passes through the sleeve is a true cylinder and a collar (37), screwed and keyed to it, acts as a piston while the gun is its own piston-rod. The *sleeve* (33) bears on the gun only at its ends, where stuffing-boxes (39) are fitted, and the annular space between it and the gun is filled with recoil liquid through the filling-hole (42). The *counter-recoil spring* (35) is held, in the usual state of slight initial tension, between the piston and the rear cylinder-head. The inside of the cylinder is rifled with grooves of the common form; ribs at the top and bottom fit into recesses on the edge of the piston and prevent the pressure of the projectile on the rifling of the bore from rotating the gun. *The trunnions* (17) are parts of the sleeve and rest in seats in the trail (1) where they are held by cap-squares. The *trail* is mounted on a heavy axle (2) which is in turn supported by the wheels (3); the latter are secured by linch-pins (5) which are easily removed when dismounting the carriage. The rear end of the trail is supported when on the march by the trail-wheel (24)—shown in its dotted position. Before firing, the pin (26) is removed and the wheel hinged upward, as shown, to permit the spade (22) to rest on the ground and help restrain the carriage from running to the rear during recoil; in this the spade is assisted by a brake (12) acting on the tire of each wheel. The trail contains an *accessory box* (20), sockets for the trail-bar (31), racks (28) and (29) for bar and sponge-staff and bearings for the elevating shaft (45). The latter, worked by its hand-wheel (50), bears an elevating-worm (46) which gears with the elevating-arc (44) of the sleeve; the worm-spring (47) surrounds the shaft between the worm and the front bearing (48),—its function is to take up the jump. It is

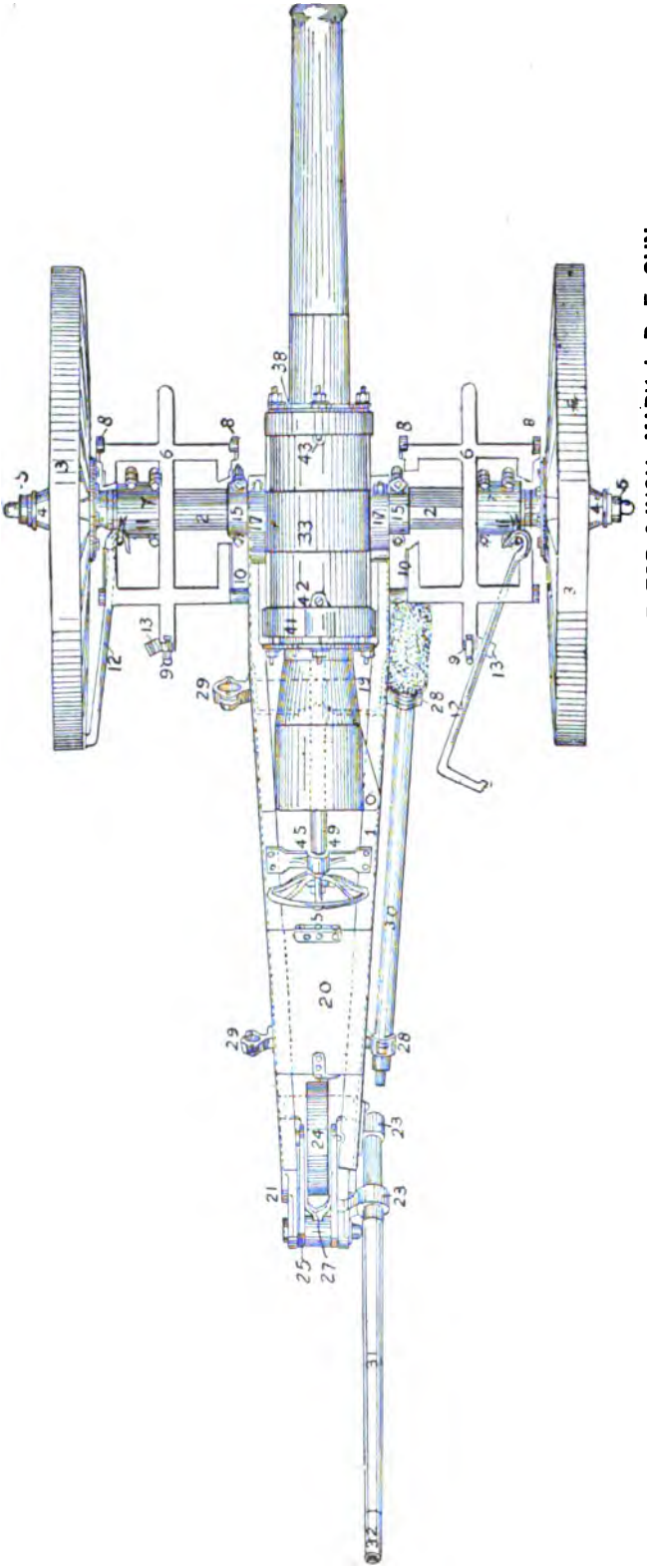
to be noted that the gun cannot be trained with respect to the mount, the trail must be moved by means of the trail-bar. The *sights* (not shown) are of the open type and are fitted to the gun and sleeve—the sight-bar is marked up to 3200 yards. The *ammunition* is carried in four ammunition-boxes (51), each containing eight rounds, which rest on the carriage, two on each side, where they are secured on the racks (6). With this mount the recoil is only seven inches which is rather too short for a light carriage and in some cases the sleeve has been damaged. A small air-chamber is now being fitted on the top of the forward end of each cylinder; this will allow for the expansion of the liquid, as the recoil mechanism becomes heated from continued firing, and will give better cushioning. The *total weight of the gun, carriage,* and *thirty-two rounds* of ammunition is 1830 pounds.

12. The Mark II field carriage (see Plate III) differs from the Mark I carriage principally in the form of the elevating-gear, the recoil-mechanism and in giving the gun a small arc of train independent of the carriage. The axle, wheels, ammunition boxes, trail-wheel, spade, brakes etc. of the older design are retained and the trail is in general the same, except at its upper end where it conforms to the new arrangements mentioned above. Forged on the lower side of the breech of the gun is a lug to which the piston-rod (7) is attached. The gun recoils through a *bronze sleeve* (33) cast in one with the recoil-cylinder (4), and is prevented from turning, from the action of the projectile on the rifling, by a key on each side which fits in grooves in the slide. The *recoil-cylinder* is of the common hydraulic type, with counter-recoil spring divided into three sections, separated by disks, and a counter-recoil checking device in the forward bonnet; it is to be noted that the cylinder is unusually long and of small diameter—the normal recoil is fifteen inches, much greater than have ship's guns of equal power; it is impracticable to control the recoil in a field-mount (which is kept as *light as possible*), in the short space usual with ship's mounts; besides this, lengthening the recoil reduces the jump of the carriage.

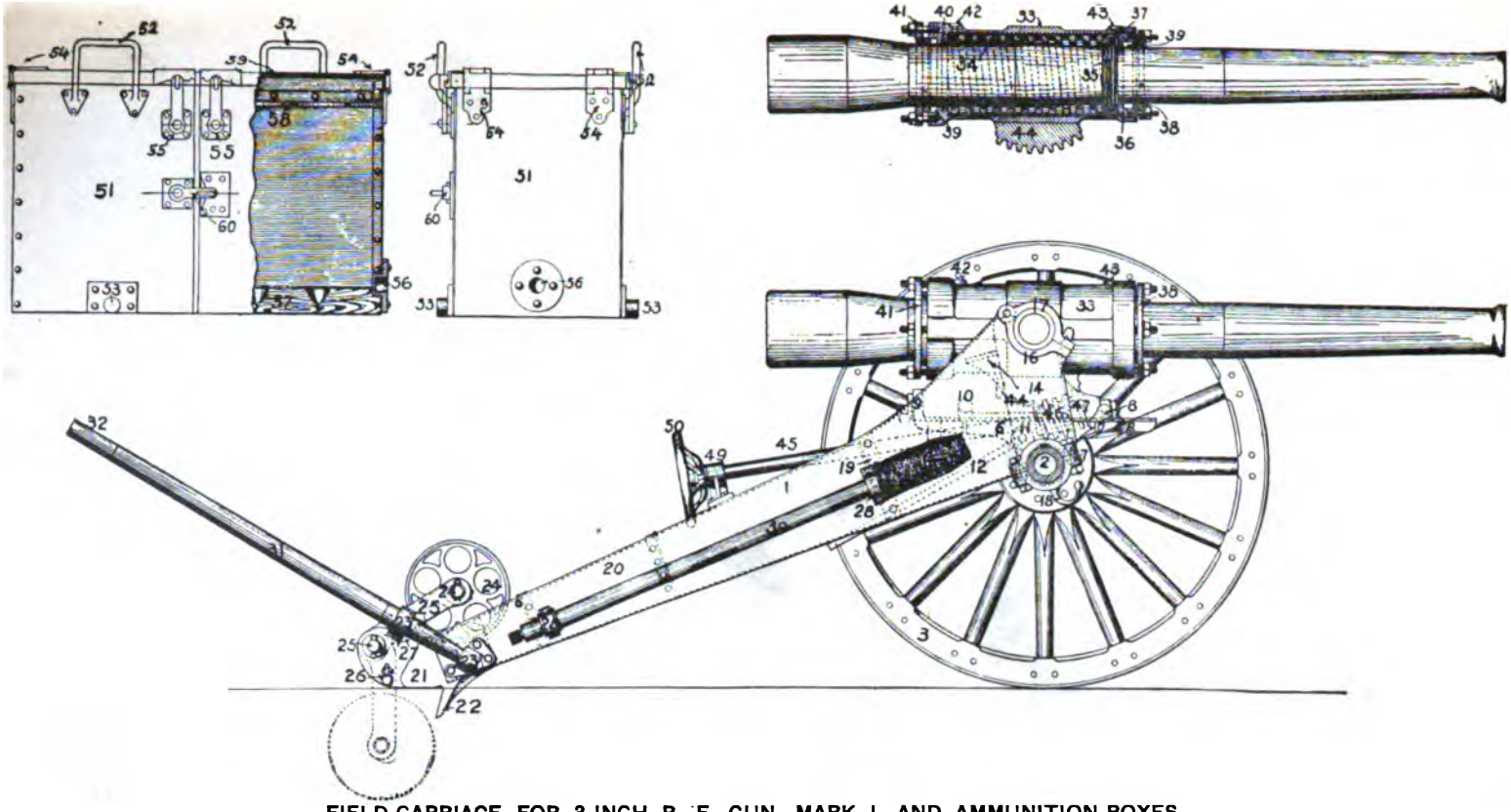
13. Instead of trunnions, there is employed a device for securing the slide to the rest of the mount which is characteristic of

the carriage. From the lower side of the cylinder a heavy lug projects downward and an interrupted collar is cut on its inside surface; a similar collar is cut around the block (9), which embraces the axle (2) but turns on it as the gun is elevated; the collars of the two parts are engaged by a bayonet-joint and ball-bearings between them, as shown in the plate, reduce friction in training. The rear end (10) of the cylinder is dovetailed over a T-shaped bar (49) to which the elevating-shaft (46) is indirectly secured, but which has no lateral motion; the shaft of the training-wheel (11) turns in bearings in the same part and its worm-gears in an arc on the cylinder and slide-casting. By the *training-wheel,* the gun may be moved through an arc of three degrees—larger arcs of train are given by moving the trail around. The *elevating-wheel* (50), placed near the training-wheel, turns a shaft on which is a bevel-gear wheel (52); the end of the shaft, projecting through, and the heavy bolt (53) screwed through the opposite side of the trail, act as trunnions to hold the collar (13) of the elevating-nut,—the device must permit a slight angular movement of the nut as the gun is elevated or depressed. The *elevating-nut* (47) gears with the elevating-wheel through bevel-gearing, and, being restrained from all but circular motion, works the threaded shaft (46) up or down as it is turned. This shaft is coupled to the framing which bears the training-gear and elevates or depresses the gun by swinging the whole of the upper mounting on the axle (2).

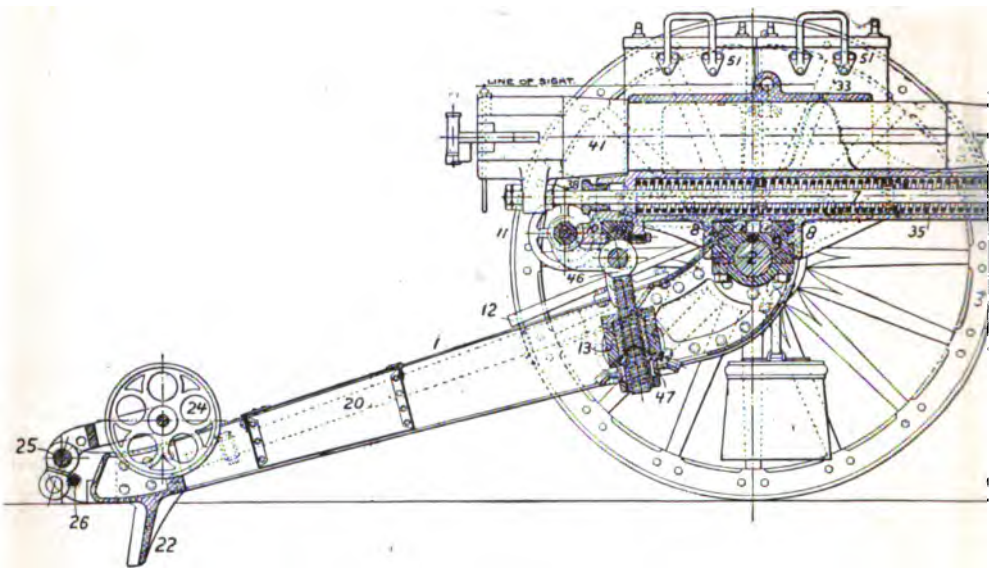
14. A limber, carrying 48 rounds, in boxes like those carried on the mount, is supplied with the Mark II carriage. These guns, being low-powered, have only a small charge of 400 grams of smokeless powder. Shrapnel, with combination time- and percussion-fuses, are the only projectiles furnished with the field-piece; the ammunition is "fixed"—put up in a short cartridge-case.

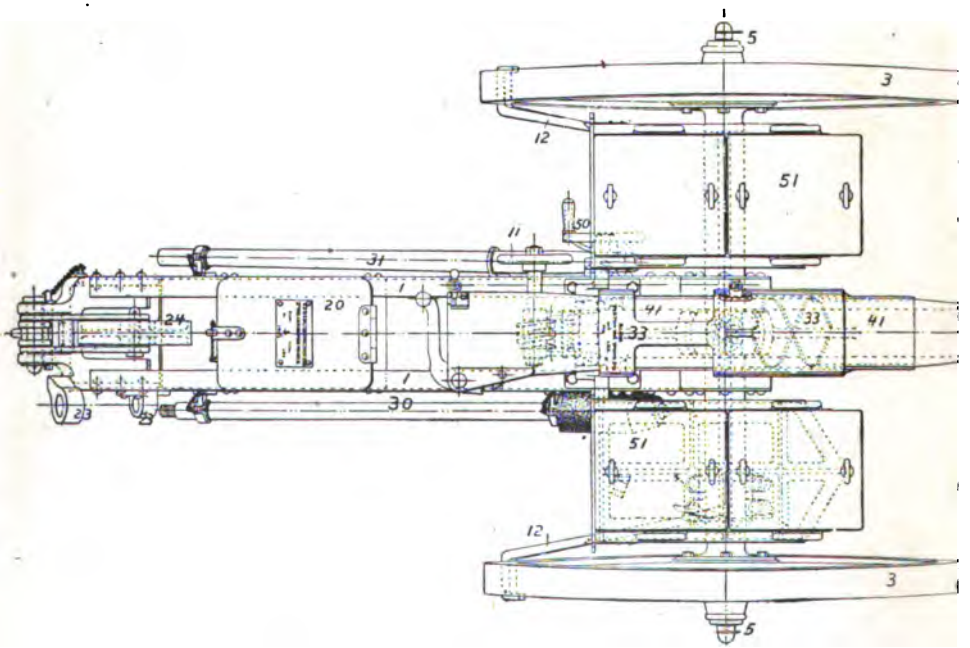


FIELD-CARRIAGE FOR 3-INCH, MARK I, R. F. GUN.
Top View.

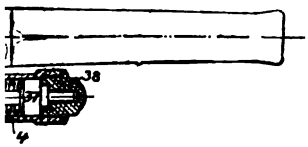


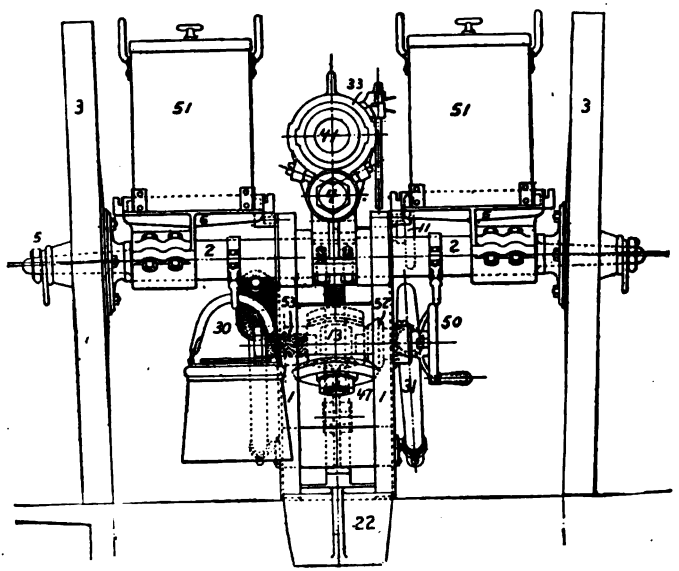
FIELD-CARRIAGE FOR 3-INCH R. F. GUN, MARK I, AND AMMUNITION-BOXES.



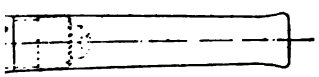


THE MARK II, 3-INCH





Front View.



CHAPTER XXV.

EXPLOSIVES.

[*From Ingersoll's Text-Book of Ordnance and Gunnery, revised.*]

1. General discussion.—The explosive now most commonly used for all guns is smokeless powder. Since the elastic strength of guns to withstand powder pressure has a limit very much below that attainable by the explosion of smokeless powder in a confined space, the effort of powder-makers is to produce an explosive that will not give a maximum pressure, with a given weight of charge and projectile, greater than the safe working-limit set for the gun—usually from sixteen to seventeen tons with guns of the present type—and which will at the same time give a high initial velocity to the projectile.

2. The ideal powder is that which would, on ignition of the charge, burn in such a manner that the pressure would rise rather quickly to the maximum allowed, and thereafter maintain that pressure throughout the bore while the projectile is travelling from its seat to the muzzle. In this case the guns would be made in the form of a cylinder. That they are not so made is due to the fact that in practical experience the pressure falls from the maximum point to the muzzle, the amount of fall depending upon the character of the powder, the size and shape of the grain, the law of burning, and many other practical causes.

3. The present aim of the powder-manufacturer is, therefore, to make powder so that it will reach quickly the known pressure which guns of the proper thickness will withstand, and so that it will maintain this pressure as nearly as possible while the projectile moves out of the bore. It is apparent, therefore, that the powder should not flash off too quickly at first, and that it must burn with increasing rapidity after the shot begins to move.

4. Progressive powders.—Such powder is called *progressive.*

A glance at any gun will convince the observer that perfection is not yet by any means attained.

NOTE.—The subject of gunpowder is treated in Chapter XXVI.

Definitions.

5. Explosion.—An explosion may be considered as the result of a chemical change in a solid or liquid body, by which a great volume of highly expanded gas is suddenly or very quickly produced from it.

6. Explosives may be defined as a class of bodies the molecules of which are in such a state of unstable equilibrium that a slight disturbing agency will cause a chemical change among them, the effect of which change is to produce suddenly a very large volume of highly expanded gas.

7. Explosive reaction is the term applied to the chemical change which takes place in explosives when their equilibrium is destroyed.

8. Explosive effect.—The blow, or impulse, given by the sudden production of the large volume of gas is called the explosive effect.

9. Classes of explosives.—There are two classes of explosives, viz., *explosive mixtures* and *explosive compounds.*

10. Explosive mixtures.—An explosive mixture consists of combustibles and supporters of combustion, mixed so that by their mutual action a large quantity of gas is developed. The most important explosive mixture is ordinary *gunpowder.*

11. Explosive compounds.—An explosive compound is a single definite chemical compound, the particles of which rearrange themselves to form the gases evolved by explosion.

12. The more important of the explosive compounds in extensive use for various purposes are *fulminate of mercury, fulminate of silver, nitro-glycerine;* gun-cotton, and most smokeless powders, are also chemical compounds. Explosive compounds are much more sudden and, weight for weight, are usually much more violent in their action than explosive mixtures.

13. Classes of explosive mixtures.—The combustible bodies that may be used are very numerous, but practically there are

only two bodies which are used to supply the oxygen necessary for burning the combustible. These are *potassium nitrate,* or saltpeter, and *potassium chlorate.* Therefore all mixtures may be divided into two classes, namely, nitrate and chlorate mixtures.

14. Nitrate mixtures.—The most important one under this head is that composed of saltpeter, sulphur, and charcoal. In various proportions this mixture is employed for very many purposes; the action is the same in all cases, so that the explosion of gunpowder fully illustrates them all. Nitrate mixtures are not greatly susceptible to friction, concussion, or percussion. In general, the explosion of these mixtures is comparatively slow.

15. Chlorate mixtures.—In general, the explosion of these mixtures is much more sudden and violent than that of nitrate mixtures, and they are also much more sensitive to percussion, concussion, and friction. Generally speaking, all chlorate mixtures are unsafe, and dangerous to handle or transport on account of their susceptibility to accidental explosion. It is stated, however, in the annual report of H. B. M. Inspectors of Explosives for 1900 that several chlorate compositions have passed the storage stability tests and are now licensed for use and carriage in Great Britain.

16. Orders of explosion.—When an explosive is ignited by heat and converted into gas by gradual combustion, as is the case with gunpowder, the explosion is said to be *low,* or of the second order. When, however, the whole mass of the body is suddenly and violently converted into gas, the explosion is said to be *high,* or of the first order.

17. Means of causing explosion.—The application of heat, either directly or indirectly, is the principal means of causing an explosion: directly, as by a match, a red-hot iron, etc.; indirectly, by friction, where the mechanical energy of rubbing is converted into heat; by percussion, where heat is generated by the direct application of a blow; or by concussion where heat is generated by a jar or shock communicated through a second body.

18. Method of producing explosion.—(1) The circumstances under which an explosion takes place create a marked difference in the effect produced. Everyone is familiar with the different effects produced by firing gunpowder in the open air and firing it

in a confined space; but, apart from this, the mode by which it is fired exercises immense influences both upon the force and the rapidity of its explosion.

(2) Suppose that a quantity of *fulminate of mercury* be exploded within a mass of any other explosive. Apart from the flame produced, a blow will be given by the gas suddenly formed by the fulminate, which will act upon the surrounding explosive *percussively*, like the blow of a hammer upon an anvil. The very rapid motion of the particles of gas will give them a force, as regards any resisting body, similar to that exercised by a solid having a great velocity, against any obstacle in its path.

Detonation.

19. When the flame of the fulminate is applied directly to the explosive, the chemical change is initiated at the point of application, and if the flame alone were considered, would gradually spread from this point through the mass; but the percussive blow is extended through all parts of the body with very great rapidity, greatly expediting the explosion of the charge. In certain cases the effect is practically simultaneous throughout the whole mass of the body, thus producing *detonation*, the effect of which is much more powerful than that of an ordinary explosion. Thus we see that detonation is really nothing more than an exceedingly rapid explosion. In an ordinary explosion, like that of powder in a gun, much force is lost by the slowness of the action. As gases expand heat is absorbed, so that if the gases can expand as they are formed, much of the heat of the chemical reaction is absorbed, diminishing the sharpness of the explosive effect, which is therefore not sudden, but gradual. With a force gradually generated and exerted, we have a propulsive effect, but a detonation has a disruptive violence, which may become almost irresistible.

20. Explosives capable of detonation.—Experiments indicate that each high explosive has a mode of detonation peculiar to itself; and it is possible that nearly all explosives could be detonated if the correct method were resorted to in each case—if each were subjected to the form of percussive blow to which it is

most sensitive. It is claimed, however, that the U. S. Navy smokeless powder cannot be detonated. Gun-cotton seems to have a greater range of susceptibility to different modes of firing than any other explosive agent. It can be made to burn slowly without explosion, and the rapidity of its combustion can be increased up to the point of detonation. Nitro-glycerine, as before stated, appears always to detonate. (It is not sensitive to flame as directly applied.) Fulminate of mercury is a detonating substance, but the quantity of gas given off is comparatively small, hence the limited range of its destructive effect.

21. Detonation, how produced.—Detonation can only be produced by the application of the requisite blow or shock, and this is usually accomplished by means of a detonating fuse containing the required amount of *fulminate of mercury,* the amount differing for each explosive.

"Fulminate" is the general name for a class of explosives which are compounds of fulminic acid with a base. They are all more or less explosive by the action of the heat of friction. The fulminates of mercury and silver are the most important.

22. Fulminate of mercury has been found to be by far the best agent for producing detonation; less of it is required than of any other explosive. Nitro-glycerine is much more powerful than fulminate of mercury, but while a certain amount of the latter will detonate gun-cotton, seventy times as much nitro-glycerine will not accomplish it. *Chloride of nitrogen* and *iodide of nitrogen* are much more violent than fulminate of mercury, yet a larger quantity of them is required to produce detonation. These facts indicate that there is some peculiarity in the impulse given by the firing of fulminate of mercury that affects other explosives more powerfully than that given by any other body, though the latter may be the stronger. It may be considered that this is owing to a peculiarity of vibration, or *wave motion,* due to the explosion of fulminate of mercury, which causes greater disturbance among the molecules of other explosives than the vibrations produced by any other detonators.

23. Preparation of fulminate of mercury.—Fulminate of mercury is prepared by dissolving one part of the mercury in twelve of nitric acid, sp. gr. 1.42, aided by a gentle heat. As soon

as the mercury is dissolved, add eleven parts of alcohol, sp. gr. 0.87. A brisk action will ensue, and the solution will become turbid from the separation of crystals of the fulminate. Dense, white clouds are also evolved at the same time. When the action has subsided the vessel may be filled with water and the fulminate allowed to settle, after which it is collected on a filter, washed, and dried by exposure to the air. When dry it must be handled cautiously, as it explodes by friction or percussion, especially when in contact with particles of sand or glass. It is also exploded by heating to about 300°, by the electric spark, and by contact with concentrated nitric acid or sulphuric acid.

24. When wet it will not explode. Its explosive force is not much greater than that of gunpowder, but it is much more sudden in its action.

25. The readiness with which it is fired makes it an excellent agent for exploding other substances, and this gives it its value. It is used in percussion caps, primers, and fuses—not pure, but mixed with niter, mealed powder, and other substances, because it is necessary to moderate its explosive property, since it is otherwise too rapid and violent for the purpose. It is sometimes mixed with chlorate or nitrate of potash, and ground glass is often added to increase the sensibility of the mixture to explosion by percussion.

26. A new fulminate has recently been invented in Austria, intended to replace fulminate of mercury for military purposes. It is claimed to be quite as effective as a detonator and much less sensitive than fulminate of mercury. If so, the gain will be very great, as the danger from handling explosives and ammunition generally will be lessened by the introduction of a safer fulminate. The composition of the new substance is secret, but it is said to contain copper, ammonium nitrate, potassium nitrate, sulphur and aluminum.

27. Illustrations of explosion by detonation.—(1) The practical value of this mode of developing the force of explosive agents is very great. The necessity of confining gunpowder and other explosive materials in strong receptacles for the purpose of developing their explosive force, is greatly reduced, and indeed

entirely dispensed with in the case of charges fired under water, when detonating fuses are used as the exploding agents.

(2) Masses of hard material of great size or strength, such as blocks of hard rock, large iron castings, or thick bars of iron may be broken up by simply placing upon one of their surfaces a comparatively small charge, quite unconfined, of compressed gun-cotton, or of a nitro-glycerine preparation, and exploding it by means of a detonating fuse.

28. In such operations the destructive effect of the detonation will be increased by covering the charge with sand or other material, but in hurried operations good results may be obtained with either of the materials specified, by detonating them when freely exposed to air.

29. For hasty demolition of buildings and of military works, the explosion by detonation affords most important facilities, reducing the difficulties, dangers, and cost of such operation to a minimum.

Explosion of Gunpowder.

30. The phenomenon of explosion of gunpowder may be divided into three parts, viz., *ignition, inflammation,* and *combustion.* By ignition is understood the setting on fire of a particular part of the charge; by inflammation the spread of ignition from grain to grain; and by combustion, the burning of each grain from its surface to center.

31. Ignition.—Ordinary gunpowder may be ignited by the electric spark, by contact with an ignited body, or by a sudden heat of 572° F. A gradual heat decomposes powder without explosion, by subliming the sulphur. Flame will not ignite brown powder unless it remains long enough in contact with the grains to heat them to redness. Thus the flame from burning paper may be touched to grains of brown powder without igniting them, owing to the slight intensity of the flame and the cooling effect of the grains. It may be ignited by friction or a shock between two solid bodies, even when they are not very hard. Experiments show that gunpowder may be ignited by the shock of copper against copper, copper against iron, lead against lead, and even lead against wood; in handling gunpowder, therefore, violent

shocks between all solid bodies should be avoided. The time necessary for igniting powder varies according to circumstances. For instance, damp powder requires a longer time than powder perfectly dry, owing to the loss of heat consequent on the evaporation of the water; a powder, the grain of which has an angular shape and rough surface, will be more easily ignited than one of rounded shape and smooth surface; a light powder more easily than a dense one.

32. Smokeless powder is not ignited as easily as black or even brown powder, and for this reason an *ignition charge* of the former is used for each charge of smokeless.

33. Inflammation and combustion.—When grains of powder are united to form a charge, and fire is communicated to one of them, the heated and expansive gases evolved insinuate themselves into the interstices of the charge, envelop the grains and ignite them one after another.

34. The propagation of ignition is called *inflammation,* and its velocity, *the velocity of inflammation.* It is much greater than that of combustion, and it should not be confounded with it. When powder is burned in an open train, fine powder inflames more rapidly than coarse; such, however, is not the case in firearms, owing to the diminution of the interstices. If a charge were composed of mealed powder, the flame could no longer find its way through the interstices, and the velocity of inflammation and combustion would become the same. The ignition charge used with smokeless powder serves not only to ignite the powder but to increase the velocity of inflammation.

35. Now, supposing one grain or particle alone be ignited, it will first be inflamed over its whole surface, and the progressive combustion will take place from the exterior to the interior. Its *rate of combustion* will therefore depend upon both its shape and size, leaving out entirely, for the present, the question of density and hardness. A grain of spherical or cubical form will expose less surface to ignition in proportion to its volume than one of an elongated or flat shape, and will consequently require a longer period for the combustion of its entire mass; the larger the grain also, the longer will be the time required for its combustion.

36. Looking, then, at one grain of powder by itself, we may say that the larger it is, and the more nearly its form approaches a sphere, the longer will its combustion take and the slower will be the evolution of the gas. When, however, we come to regard the action of an aggregation of such particles, as in the charge of a gun, the *rate of ignition* of the whole charge is also affected by the size and shape of the grain.

37. The part of the charge first ignited is that near the vent, and the remainder is inflamed by contact with the heated gas generated by the combustion of this portion, so that the rate of ignition of the whole mass will be regulated by the greater or less facility with which the gas can penetrate throughout the charge, which is itself dependent upon the shape and size of the interstices between the grains. If the grains be spherical and regular in form, the interstices will be comparatively large and uniform, and the gas will penetrate the mass with facility; again, the larger the grains, the larger the interstices between them. If, on the other hand, they be flat or flaky and irregular in shape, the passage of the gas will be more difficult, and the rate of inflammation of the charge will be reduced.

38. We see, therefore, that the considerations which affect the more or less rapid combustion of an individual grain of gunpowder, also affect the rate of ignition of a charge of such grains, but in an opposite direction; so that a form of grain, which will individually burn rapidly, may offer an increased resistance to the passage of the heated gas through the charge, and thereby retard its ignition, while a grain which will burn more slowly may allow of the charge being more rapidly ignited. In the case of perforated grains, however, the rates of ignition and combustion are both increased by the perforations.

39. By varying the size and shape of the grain alone, a powder may therefore be obtained, a charge of which shall be ignited rapidly throughout, but burn comparatively slowly, or one which will be ignited more slowly, but when once inflamed burn very rapidly. It is necessary to draw a clear distinction between a rapidly igniting and a quickly burning powder.

40. Velocity of combustion.—The velocity of combustion is

the distance passed over by the surface of combustion in a second of time, measured in a direction perpendicular to this surface.

41. *The velocity of combustion varies with the purity, proportions, trituration, or incorporation of ingredients, density, and condition* of the ingredients; also with the pressure and temperature under which the powder is burned.

42. Effect of temperature on combustion.—The heat developed increases with the charge, and as the velocity of the gases increases with their temperature, it is therefore evident that a large charge is consumed quicker than a small one; it is also true that the quantity of heat absorbed by the surface of the bore is much less sensible when the charge is great than when it is small; that is, the heat absorbed is proportional to the surface, or the square of the caliber of the gun, and the heat developed increases as the cube of the caliber.

43. The resistance of the projectile.—When the projectile offers a great resistance its motion in the bore is less rapid, and it evidently follows that the inflammation takes place in a space which diminishes as the resistance increases. The smaller this space, the more heat is generated, the higher the temperature of the gases, and the greater their velocity; and there follows from all these causes a train of effects which accelerates the inflammation and combustion of the charge.

44. The point of ignition.—When a quantity of powder is contained in a closed space all the sides of which offer an equal resistance, it is evident that the complete inflammation will be quickest when the fire is applied to the center of the charge.

45. In cannon, however, the force developed does not meet with the same resistance in all directions; the projectile yields as soon as sufficient force acts upon it; and as the combustion of the powder requires a definite interval of time, it follows that a great part of the charge is not consumed until after the displacement of the projectile.

46. *The position of the interior orifice of the vent* may influence the time required to displace the projectile, and this influences the inflammation of the charge. For example, with the regulation vent, it is the rear part of the charge which first takes fire; the inflammation is communicated to the adjacent parts and promptly

reaches the projectile; the gases expanding displace it, and the inflammation takes place in a larger space than that at first occupied by the charge.

47. Density.—The density and hardness of the grains of powder are of quite as vital importance as their size and form, in determining the rate of ignition and combustion of a charge.

By density is meant the quantity of powder actually present in a given bulk.

48. It is important that this quality should not be confounded with hardness. A substance may be very hard and yet be of a low density. A powder with a very hard surface may be really less dense than another, the surface of which is softer. Of course, very high density cannot be communicated without producing a considerable degree of hardness; but powder can be made hard without rendering it very dense, by pressing the dust in a comparatively dry state.

49. Hardness seems to bear a direct relation to the power exerted in compressing, while density does not. Black powder-dust, at a high degree of moisture, say six per-cent, can be made very dense by application of moderate pressure, while that of 1 per-cent can only be brought to the same point in density by the exertion of enormous force. Of the two, the latter will be the harder powder.

High Explosives.

50. High explosives are used in naval warfare for the charges of torpedoes, submarine mines, for the bursting charges of special shell, and for the destruction of the enemy's resources in machinery, fortifications, buildings, bridges, etc., when necessary and desirable.

51. There are numerous high explosives, the principal ones being: *nitro-glycerine, gun-cotton, explosive gelatine, dynamite, picric acid* and its compounds, *lyddite, maximite, dunnite, emmensite,* etc. Of these, gun-cotton, maximite, and dunnite are preferred in the United States for military purposes. Many others are used in Europe, and new forms are being constantly produced for which extravagant claims are made.

52. Nitro-glycerine * was discovered in 1847 by A. Sobrero, and is a nitro substitution produced by the action of nitric and sulphuric acids on glycerine. In order to insure stability and reduce its sensitiveness to shock to a minimum, no cheap materials should be used in its manufacture; the glycerine should be above proof, the nitric acid of a specific gravity of 1.5 and the resulting explosives carefully washed to remove all traces of free acid. When ignited in small, unconfined quantities it burns, but with close confinement it explodes either by ignition or when heated to 257° F. It freezes at 40° F., in which state its sensitiveness to concussion and detonation is very much reduced. It can be detonated by shock, gunpowder-fuse or detonator, and generates six times as much gas as gunpowder, which is expanded by the great heat produced to occupy thirteen times the volume. It is insoluble in water. Its use is now generally confined to the dynamite and gelatine forms.

53. Gun-cotton was first manufactured by Schönbein in 1845, but proved dangerous to handle until it was rendered safe by the method of purifying, pulping, and compressing it. It is produced by the action of sulphuric and nitric acids on cellulose in the proportion of three parts of sulphuric to one part of nitric acid. Under the action of these acids, according to their strength and methods employed, trinitro, binitro, and mononitro cellulose are produced, gun-cotton being the first-named, viz., trinitro cellulose. It is only soluble in acetone; unconfined and ignited it burns away rapidly; struck with a hammer on an anvil a part of it explodes, the remainder being blown away; when heated to a certain temperature it explodes, and when confined or compressed, it explodes from shock, heat, or detonation.

54. To Mr. E. O. Brown is due the credit of discovering that wet uninflammable gun-cotton is capable of being detonated by a strong detonator, or by an ordinary detonator with a priming charge of dry gun-cotton, the size of which depends upon the percentage of water contained. This discovery greatly increases the value of gun-cotton as a military explosive, not only for submarine work, but also as an explosive for shells; for wet gun-

* *Naval Intelligence Annual*, 1890.

cotton is not affected by shock, will not explode when penetrated by rifle bullets, nor upon shock of discharge when loaded in shells; it is comparatively insensible to sympathetic explosion, and is not exploded by heat. In 1871 the English government tested this last-named quality by burning in bonfires two lots, of a ton each, of gun-cotton, containing thirty per-cent moisture. In one case the explosive was in disks in a closed tank, and in the other it was divided among eighty closed packages. In both cases the gun-cotton burned away without explosion.

55. Steps have been taken to coat disks of wet compressed gun-cotton, in order to prevent decomposition by the evaporation of moisture. In 1883 Von Forster and Wolff patented the process of dipping gun-cotton in acetic acids for a few seconds which dissolves the cotton on the surface and forms a coating. But this was found to crack, so they now coat the disk with paraffine, and only treat the hole in this manner to facilitate detonation. Schulhof has patented a so-called water-proof gun-cotton which is said to possess non-hygroscopic qualities, to be insensible to shock or blow, and to be capable of exploding by detonation or heat of over 300° F. He impregnates dry gun-cotton with molten tallow or mutton fat, getting rid of the superfluous grease by pressure and washing with bisulphuret of carbon and benzine.

NOTE.—The details of the manufacture of gun-cotton are given in Chapter XXVI.

56. Wet gun-cotton is known to be a perfectly safe, uninflammable and inert explosive in the absence of a strong detonating force. It may consequently be stored aboard ship, or conveyed and used with land forces, without any special precautions and without the slightest risk from any cause. Its keeping qualities are excellent.

(1) Wet gun-cotton contains about 20 to 25 per-cent of water. With a delay-action fuse it has given excellent results as a bursting charge for shells, having been fired through comparatively thick armor-plate before exploding. It seems to be superior to the English lyddite in this respect, the latter being more locally violent.

(2) Wet gun-cotton charges for torpedoes are usually made up of small blocks or disks to fit the head. Recently, however, for-

eign manufacturers have pressed the charge into one solid mold exactly fitting the head of the torpedo, with a hole through the center for the primer.

57. Gun-cotton in shell.—Dry gun-cotton may not resist the shock of discharge of a powder gun under service conditions. Experiments in England from 1864 to 1867 showed that charges of 3 pounds in specially lined shell, when fired with an initial velocity of 1300 f. s., were exploded prematurely; and although 18-pound charges have been successfully fired from a 24-pounder gun, and 6½-pound charges from a 20-pounder gun at the Torpedo Station, it simply indicates the perfection reached in its manufacture at that place.

(1) When wet or saturated with paraffine, gun-cotton is safe for use and will penetrate armor without explosion.

(2) As generally used for explosive charges of shell, wet gun-cotton is compressed into disks and prismatic or cylindrical grains.

58. Gun-cotton for submarine mines.—Experiments in England have shown that with a ship of the Hercules type, with double-bottom empty, and coal-bunkers full, 95 pounds of gun-cotton exploded in contact will sink her; 220 pounds at 30 feet horizontal distance inflicted no serious damage; and 500 pounds at a horizontal distance of 100 feet will probably seriously damage the pipes and machinery. Wet gun-cotton, in addition to the fulminate primer, requires about 1 pound dry gun-cotton disks to cause an explosion of the first order.

59. Blasting gelatine was invented by Nobel in 1879, and is composed of finely divided nitro-cotton dissolved in nitro-glycerine at a temperature of 100° F., the effect of the combination being to supply the requisite amount of oxygen to insure complete combustion. It contains from 93 to 95 per-cent of nitro-glycerine, being more and more gelatinous in proportion to the quantity of nitro-cotton, the thinner being the more susceptible to detonation and liable to liquefy and exudate. When slowly heated it detonates at 400° F. It is less sensitive to blows than either nitro-glycerine or gun-cotton, and requires a strong detonator and close confinement to develop its full force, not being sensitive to detonation by influence. It is unaffected by water, and is more sensitive when in a frozen state. Pure ingredients are essential to

insure its stability. It freezes at a relatively low temperature and is then more sensitive to explosion by concussion.

60. Explosive gelatine is blasting gelatine with the addition of a certain amount of camphor, which reduces its sensitiveness. The proportion generally used is nitro-glycerine 89 per-cent, nitro-cotton 7 per-cent, and camphor 4 per-cent. It burns at 570° F., requires specially strong detonators or ordinary detonators with gun-cotton or dynamite primers, and is less sensitive than most of the high explosives. It is insensitive to shock, rifle balls having been fired into it at short range without exploding it, and it is believed to be as stable as gunpowder when manufactured of pure ingredients. It is unaffected by immersion in water.

61. Dynamites are explosives in which 75 per-cent nitro-glycerine is absorbed by some porous substance, thus rendering it safer to handle and less liable to explosion from shock. They are of two classes, viz.: (1) those with an inert base; and (2) those with an explosive or combustible base.

62. Dynamite No. 1 is the one most commonly used and belongs to the first class, consisting of nitro-glycerine absorbed by kieselguhr, or rotten stone, from which the water and organic matter are driven out, in the proportions of 75 per-cent nitro-glycerine and 25 per-cent kieselguhr. It can be detonated by shock, and by a metallic gunpowder-fuse or detonator, its sensitiveness increasing with the temperature, and it explodes at 360° F. It freezes at 40° F. and remains frozen at a considerably higher temperature, in which state it is insensitive to shock, being unaffected by rifle bullets fired into it, but is more susceptible to explosion by ignition. Great care is necessary in thawing it, as the records of mining accidents show that 95 per-cent of them are caused by this operation. Frozen cartridges are not susceptible of detonation, but loose and granular dynamite, even when frozen, can be detonated, its violence being diminished. Compacted it is more sensitive to explosion by ignition than when loose, and water disintegrates it. In tropical countries it loses its strength by gradual evaporation of the nitro-glycerine. Herr Edward Liebert and Baron von Dahmen have produced so-called safety or non-freezable dynamites. Liebert's invention consists

in adding a small per-cent of isoamylic nitrate either to the nitro-glycerine itself or to the dynamite, but the substance Dahmen uses is not known. The latter explosive, after being subjected to a temperature of from —20° to —15° C. for 24 hours, remained perfectly plastic, exploded with almost as much force as ordinary dynamite, and also by influence. Under ordinary temperatures it is less sensitive to shock than ordinary dynamite and is slightly stronger.

63. Carbo-dynamite, invented by Boreland and Reid, belongs to the second class of dynamites, and consists of 20 parts of specially prepared cork carbon containing 90 parts of nitro-glycerine.

64. Picric acid forms the basis of a great many "ites," no less than thirty being shown in the English "Dictionary of Explosives," and on account of its peculiar qualities, it has shown itself to be a very potent instrument in the hands of charlatans for deceiving the uninitiated.

(1) Picric acid is nitrated indigo, and the color of the product is yellow instead of blue. It was used as a dye before it was known to be a high explosive.

(2) At the present time picric acid is made, not from indigo, but from nitrated coal-tar products, and is known chemically as "trinitro-phenol."

(3) When pure picric acid is loaded into an armor-piercing shell it will usually detonate by the time the point has penetrated about three inches, although there have been instances where VI shell charged with pure picric acid have penetrated a 5-inch plate.

(4) The addition of dinitro-benzol—a substance similar to picric acid but which melts more easily—renders picric acid less sensitive, and vaseline still further reduces its sensitiveness. For armor-piercing shell a mixture of:

87% picric acid,
10% dinitro-benzol,
3% vaseline,

is sufficiently insensitive, it is claimed, to penetrate almost any thickness of armor with a proper delayed-action fuse.

65. Emmensite was invented in 1888 by Dr. S. H. Emmens

and belongs to the picric powders. The compounds bearing the name emmensite all contain a nitrated carbolic acid which is produced by dissolving, at a gentle heat, an excess of commercial picric acid in concentrated fuming nitric acid (50° to 52° C.), the solution, on evaporation, depositing it in yellow prisms. These prisms are heated in a dish until they become semi-liquid, and are then mixed with a mineral salt, some other ingredients being added for special purposes. There are four grades, the best, No. 1, consisting of equal weights of the nitrated carbolic acid, nitrate of soda, and nitrate of ammonia. The cake so produced is then pulverized in a mortar, the smaller the grains the more rapid being the explosive action. When heated it melts into a resinous state without exploding, and a match ignites it with great difficulty. When struck by a hammer on an anvil, or a rifle bullet at short range, only the part immediately in contact explodes, and it has been fired as a projectile from small arms against iron plates without exploding on impact, thus proving its insensitiveness to shock. Its keeping properties have been put to a two years' test without its deteriorating, and when mixed with some substance to act as a reducer it can be used as a propellant. Its specific gravity is said to be 1.8. Although it is hygroscopic, its strength is but slightly affected by repeated saturation with water, and subsequent drying.

66. Experiments have been made with emmensite as the bursting charges of high explosive shell and it has been generally successful.

67. Lyddite.—The English lyddite is a picric acid compound modified with dinitro-benzol and vaseline. Remarkable claims are made for this explosive, and it has been used so extensively by the British that it merits attention. It is claimed that it may be stirred with a red-hot iron, thrown into a furnace or boiled away in a saucepan without explosion. It may be melted in hot water and then poured into shells, where it forms a dense, compact mass, and may be fired through thin armor. When set on fire with a hot iron it will burn while the iron is in contact with it, but the flame will go out when the iron is removed. As a bursting charge it is violent and blows the shell into many very small fragments.

68. The effect of lyddite against ships is terrific when the shell penetrates between decks. It will be very effective against unarmored or thinly armored ships, but as yet it has not penetrated as much armor as some other high explosives.

69. Lyddite in the Boer war.—The British used lyddite extensively for bursting charges in shell against the Boers. A writer on this subject states: "The lyddite shell has proven one of the distinct disappointments of the war. It has no effect whatever against intrenchments. On exploding, which it almost always does as far as I could judge, it only makes a small hole about a foot deep and two feet in circumference, and breaks into a few fragments. . . . The poisonous gases confined in a close space would be very destructive, but in the open air they are too quickly dissipated to do any injury." Another writer on the same subject says: "The results obtained by the large lyddite shells have been slight. Their effect on men sheltered behind boulders or posted in deep trenches was nil. This was proved at Paardeberg, when 98 pieces of various calibers bombarded Kronje's camp—a square of less than 1000 yards—at 2500 yards' range for eight days and nights, and only put *hors de combat* some 100 men out of 4140. The demoralization produced by the noisy explosion of the lyddite soon passed away, the effect of the shell being so feeble. Boers were seen to be thrown down by the wind of the projectile bursting close by them and even their clothes were torn off, but they got up again without a scratch. *The effect of shrapnel on the contrary was always dreaded.*"

70. This testimony regarding high explosive shell in the open is significant. In confined spaces, like the decks of a ship, the effect may be very different.

71. Maximite.—Maximite has given such remarkable results as the bursting charge in armor-piercing shells that it may come into general use for that purpose.

(1) The composition of maximite is a secret. It is claimed that it cannot be exploded by ignition or shock, and when heated in an open vessel it will evaporate like water so that the temperature cannot mount to the explosive point. The shells are filled by pouring the explosive into them. Its expansion while solidifying into

a dense and solid mass packs it so hard as to prevent the formation of air spaces. The terrific force of the explosion is shown by the regularity and character of the 7000 fragments into which a 12-inch fused shell weighing 1000 pounds has been blown. So far as experimented with, maximite appears to have excellent chemical stability and keeping qualities. Shells loaded with it have been fired through armor-plates from three to twelve inches thick and either exploded in the plate or just beyond it, showing that it will stand the shock of impact. The fuse used with it is the secret invention of Captain Dunn, U. S. Army.

(2) An account of its action, in the experiments at Sandy Hook, will be found in the chapter on " Penetration of Projectiles."

72. Dunnite.—The composition of dunnite is a secret. As a bursting charge for shells it promises to rival maximite when used with a proper delayed-action fuse.

The Use of High Explosives in Warfare.

73. As the utility of high explosives in warfare is now recognized, the desirability of regulating their sensitiveness is very apparent. The various dirigible and automobile torpedoes carry large charges of explosives, but they are limited as to range and accuracy.

74. The first successful steps toward accomplishing this problem were where very heavy charges of high explosives were projected at low initial velocities and moderate ranges, as by the Zalinski pneumatic gun; but the use of projectiles so discharged, containing 60 per-cent by weight of high explosive is limited to torpedo effect, to countermining, to mortar or high-angle fire against forts and to use against the unprotected sides or exposed decks of ships.

75. This was a great step, but progress required a still greater advance. Direct fire and penetration are desired; and in order to increase the danger-space it is necessary to reduce the height of the trajectory, and therefore increase the initial velocity which increases the range. To accomplish the penetration of modern armor, armor-piercing shell, with very thick walls, must be used; and as the space containing the bursting charge is proportionally

reduced, the necessity of a more violent bursting charge than gunpowder, and one that is not so liable to explode by the heat generated before perforation, is evident.

76. For use against exposed bodies of men gunpowder is still an excellent agent, being less local than the high explosives and not breaking the shell into such small fragments, it being maintained that to disable a man a shell fragment should weigh not less than 1 ounce and have a velocity of 500 f. s., which is equivalent to one-eighth foot-ton. The high explosive, however, in addition to its great moral effect is capable of throwing pieces of the shattered projectile to the rear, which principle is used by the Germans against men protected by bomb-proofs.

77. As bursting charges for thick armor-piercing shells, or for large demolishing charges in thin shell to be thrown inside fortifications and engineering works, the high explosives are most efficient. But when employed against armored vessels the effect is very slight unless the projectile penetrates a certain distance before explosion, in which case it attains its maximum effect. Charges as high as 500 pounds of gun-cotton have been exploded against the face of vertical armor without producing any material damage, and it is not believed that the heaviest projectile yet fired from the Zalinski pneumatic gun will seriously damage a vessel if exploded in contact with the face of the armored sides.

78. For use against torpedo-boats, Chalon states that high-explosive projectiles from rapid-fire guns are very much more effective than gunpowder projectiles from large guns. He shows that projectiles containing 22 pounds of gelatine dynamite will sink a torpedo-boat with a radius of 37 feet of the explosion, and 13 pounds, at 29 feet distance. Hence, the object to be accomplished is to so deaden the explosive that it may remain inactive until the desired moment, when it is exploded by a fuse. This has been effected to such a degree that an initial velocity exceeding 2000 f. s. has been reached; penetration of 12 inches of steel before explosion has been accomplished; and successful delayed-action fuses are now in use.

79. For use in projectiles the requirements of an explosive are essentially the same as for submarine use, excepting that the

quality of being unaffected by water is unnecessary, and its effectiveness is not decreased by being quick in its action; but non-sensitiveness to shock is of the most vital importance.

80. Résumé.—The question of high explosives is by no means definitely settled, but there can be no doubt that they will have very important uses in naval warfare.

81. For submarine mines, gun-cotton and explosive gelatine seem to give the best results. They are safe and very powerful when exploded under water.

82. For general naval use, gun-cotton is at present unexcelled. Its stability, safety, and its powerful effect when exploded by a suitable primer all combine to make it most acceptable.

83. The results obtained in the trials at Sandy Hook, described in the chapter on "Penetration of Projectiles," were apparently very favorable to maximite and the Army high explosive as bursting charges for shells, as well as a triumph for Captain Dunn's delayed-action fuse. No trials abroad have as yet given better results than these.

84. Hand-grenades and mines have been used with great effect in the land operations of the Russian and Japanese armies.

CHAPTER XXVI.

GUN-COTTON AND SMOKELESS POWDER.

Prepared by LIEUTENANT JOSEPH STRAUSS, U. S. Navy.

1. **A description of the military gunpowders** of to-day would, so far as they relate to the propulsion of projectiles, exclude all but smokeless powder. Black powder, which has been in use for nearly six centuries, is little used except for igniting smokeless powder charges, for explosive shell, for primers and fuses, and for saluting charges. Brown, or cocoa, powder so named from its peculiar color, came into extensive use some twenty years ago, but is no longer manufactured.

2. **Black powder** is an intimate mixture of 75 parts of saltpeter, 15 of charcoal and 10 of sulphur. The proportion of ingredients has been varied from time to time during the history of gunpowder, but it is a notable fact that we are using to-day the same relative quantities that were in use at the earliest times.

3. *The ingredients* after being incorporated in a suitable mill, are caked and then broken up into granules. Shell powder and powder for fuses and primers are very fine grained; ignition charges for guns up to 6-inch are made up of similar powder; while ignition charges for the larger guns are formed from the large hexagonal prisms or from a single cake of suitable size and shape. Saluting charges are made up of irregularly shaped grains considerably larger than the shell powder.

4. **Brown powder** has played such an important part in the development of the modern gun that it merits a word in passing. Its composition is similar to that of black powder, except that the proportion of saltpeter is increased and the amount of sulphur is decreased to 2 or 3 per-cent; a small amount of sugar about equal to that of the sulphur is also incorporated. The light color is due to the fact that the charcoal used is underburnt.

5. The incorporated ingredients are formed under heavy hydraulic pressure into regular hexagonal prisms having one or more axial perforations. These prisms are packed into powder bags so as to form a solid mass with the perforations continuous and parallel to the axis of the gun. The result of the peculiar composition of the powder, the size and arrangement of the grains, is to make the mass burn slowly and *progressively*, that is, to increase the ratio of burning surface to weight of unburnt powder as the shell moves forward in the bore. By this means the pressure exerted on the walls of the gun is lessened at the breech and increased at the chase.

6. Advantages of smokeless powder.—When black or brown powder is exploded in a gun, only about 35 per-cent of its weight is converted into gas, the remaining 65 per-cent being mainly dissipated in dense smoke, while a portion of it remains in the bore as solid residue. The smoke and residue are entirely inert, and instead of aiding in the propulsion of the projectile, actually reduce its initial velocity by taking away from the expanding gases sufficient force to eject the solid particles from the gun. Thus, taking the 6-inch gun, firing a projectile of 100 pounds with a charge of 50 pounds of brown powder, 17.5 pounds of gases are formed which must not only do the work of expelling the projectile at a velocity of 2100 f. s., but 32.5 pounds of solid material must also be expelled, making the projectile weigh, for the moment, virtually 132.5 pounds. Now if the propellant were of a material that could all be turned into a gas of equal force, we would have gained: 1st, the considerable advantage of a less weight of ammunition to stow and handle; 2d, a greater velocity; 3d, no fouling of the bore; and 4th, no smoke and an unobstructed view of the target after firing each shot.

7. These advantages were recognized quite early in the last century, when attempts were made to obtain a substitute for black powder, and gun-cotton was the first material extensively used for the purpose. In order to control its rate of burning, the gun-cotton fiber was spun into threads and then twisted or braided. Considerable success attended these attempts, but owing to irregular ballistic results and other accidents, the use of this material as a propellant was finally abandoned.

8. Gun-cotton.—Gun-cotton is of several varieties, *depending upon the degree of nitration the cellulose attains in the process of manufacture.* A fairly sharp dividing line may be drawn between the grades of "*high and low nitration*" in that the latter are soluble in a mixture of ether and alcohol, while the former are not. In general, this division occurs when the percentage of nitrogen amounts to 12.75; above that point gun-cotton is insoluble. Gun-cotton containing less than 12.75 per-cent nitrogen may be perfectly dissolved into a jelly-like substance, which, after the solvent is evaporated off, becomes a hard, tough, translucent mass. In this condition it burns regularly in parallel layers without smoke; it may be pressed into any desired shape, and it cannot be detonated. This material pressed into grains of the required form constitutes the U. S. Navy smokeless powder.

NOTE.—A clear distinction must be made between the gun-cotton proper, which is used as a high explosive in mines and torpedoes, and that from which smokeless powder is manufactured.

Mo-nitro cellulose represents the lowest degree of nitration and is little used; nitration is stopped at *bi-nitro* for the gun-cotton that is to be used for smokeless powder; if stopped too soon, part of the cotton will be *mo*-nitro, and smokeless powder made from such cotton might be too weak; if, on the other hand, the nitration be continued too long, *tri*-nitro cellulose (which is regular gun-cotton) will result, at least in part. This part (the high nitration part) ***will not dissolve*** in ether-alcohol, but will remain mixed in the powder as ***gun-cotton,*** and the resulting mixture might be too brusque for use in guns—in fact it might be capable of detonation. Strictly speaking, therefore, gun-cotton is usually understood to mean *tri*-nitro cellulose, while the bi-nitro lower nitration cotton from which smokeless powder is made is often called "***pyro-cellulose,***" more correctly termed nitro-cellulose or nitro-cotton.

Manufacture of Gun-Cotton. Nitration.

9. The process followed in the manufacture of gun-cotton is practically the same for all varieties, the nitration being stopped at the proper point in each case. The following is a description of the different steps in the manufacture of *nitro-cellulose*—the base of smokeless powder.

(1) Perfectly clean dry cotton is digested for 30 minutes in about fifty times its weight of a mixture of strong sulphuric and

nitric acids. During this time a reaction between the cellulose and nitric acid takes place in which nitryl (NO_2) takes the place of the hydrogen in the cellulose and water is liberated. The function of the sulphuric acid is merely to combine with the water, thus keeping the strength of the nitric acid up to the standard necessary to obtain the proper degree of nitration.

(2) The strength of the acid mixture, its temperature, the duration of the digestion period, the dryness of the cotton, and the condition of the mass of fibers as to agglomeration all exert an influence on the resulting product, both as to its nitration and solubility. The digestion is usually performed in a centrifugal wringer, and after its completion the acid is drained off and the gun-cotton is freed from residual acid as much as possible by the revolution of the centrifugal basket. When in this state it is removed from the wringer and "drowned" in a large tank of fresh water, after which it is given a rough washing in fresh water while being revolved in the basket of another centrifugal.

10. Purification of gun-cotton, pulping, poaching.—The gun-cotton (nitro-cellulose) is now transferred to large tanks and steamed for two days, the water being changed several times during the process. It is then removed to the *pulping machine,* where it is ground between knives into a fine pulp, the water being constantly changed and sodium carbonate added from time to time in order that any free acid in the cotton may be neutralized. This process generally requires about seven hours.

11. The pulp is next transferred to large circular vats called *poachers,* and is then steamed and stirred for a period of about two days. During this time fresh water is frequently added, and after a certain period of stirring the pulp is allowed to settle and the top water decanted off. This operation is repeated until all trace of alkalinity has disappeared and the pulp passes the required heat test for stability.

12. Dehydration of gun-cotton.—Before being capable of solution in ether-alcohol it is necessary to free the gun-cotton (nitro-cellulose) from water. To accomplish this it may be first wrung out in a centrifugal which reduces the amount of water to about 25 per-cent; or, if partially freed from water, it may be run through a "wet machine," an apparatus used in paper mills for a

similar purpose. The latter process leaves 40 or 50 per-cent of water in the pulp, but it is nevertheless in good condition for treatment in the dehydrating press. This press consists of a vertical cylinder with a removable bottom over which an inverted hydraulic cylinder is arranged. The overhead cylinder has a piston-head which plays in the barrel of the first cylinder below it. The piston is raised and a charge of about 50 pounds of the wet cotton is put in the press. The piston is then forced down under a pressure of about 200 pounds per square inch; this presses out some of the water and leaves the pulp in a compact mass. Twenty-five pounds of alcohol is poured in on top of the pulp, the cylinder is closed and an air pressure of 100 pounds per square inch is admitted over the alcohol. Under this pressure the alcohol is forced to percolate rapidly throughout the mass and has the effect of leaching out the water in its passage through the cotton.

13. After all the alcohol has been forced through, the cotton is subjected to a pressure of from 2500 to 3000 pounds per square inch in order to squeeze out the surplus alcohol. An amount of alcohol is allowed to remain equal to about 25 per-cent of the alcoholized cotton. When in this condition it is only necessary to add ether to the amount of half the weight of the mass in order to provide the necessary solvent for converting the nitro-cellulose into smokeless powder.

14. Colloided gun-cotton.—The chemical process of changing ordinary cotton fiber into gun-cotton does not alter its structural properties, and it remains as before nitration, long-flattened tubes. To further the purification of the gun-cotton it is necessary to divide these tubes into very short lengths, and in this condition the mass has a powdery appearance. If it were possible to compress the gun-cotton while in this state into cakes of sufficient homogeneity and tenacity as is done with black and brown powders, the rate of burning could be controlled and we would probably produce by this means a satisfactory smokeless powder. It is, however, not possible, and resort is therefore had to its property of *solubility;* the gun-cotton is dissolved in a suitable solvent (ether-alcohol), recast into a convenient form, and the solvent subsequently evaporated off. It is still gun-cotton, but in a different form, and the change is somewhat similar to that in which

ordinary sugar is dissolved in water and then re-crystallized out into rock candy.

15. In its new condition it is referred to as "colloided gun-cotton"; it burns in a manner similar to other combustible solid bodies—layer by layer from the outer surfaces—only, it supplies the oxygen for the chemical change that takes place.

Conversion of Nitro-Cellulose into Smokeless Powder.

16. Mixing and colloiding.—The gun-cotton is next thoroughly ground up in the *mixing machine* with its solvent. This apparatus consists of a cast-iron box with a bottom consisting of two half-cylinders in which helicoidal steel blades are revolved. The operation of the machine for about an hour serves to thoroughly mix the solvent (the ether being added at this stage) with the cotton and leaves it at the end of that time in a condition much resembling damp cornmeal. It is removed from the mixer and pressed into cakes weighing about 50 pounds each. The material now has the consistency and appearance of stiff glue or jelly, and is therefore referred to as *colloid.*

17. Pressing.—In order to further complete the solution, the colloid is forced through a thick steel strainer under a pressure of about 3500 pounds per square inch. It is again reformed into a cylindrical cake under 200 pounds pressure and is then inserted in the graining press to be formed into grains.

18. Graining.—The graining press consists of a horizontal steel cylinder fitted with a piston operated by an hydraulic press. The colloid is gradually forced through a die under a pressure of about 3500 pounds per square inch. The colloid issues in a continuous grain which is chopped into lengths usually about twice the diameter, and is then ready for the dry-house.

19. Form and size of grain.—The size of the powder-grain varies with the caliber; the larger the gun the larger the grain; in general terms, the lineal dimensions of grains of similar form are in direct ratio to the calibers of the guns in which they are employed. As compared to the old forms of powder, smokeless powders produce relatively large volumes of gases per unit weight of material, yet they burn away more slowly; the result is that

grains of smokeless powder for a given caliber are smaller than those of the black and brown varieties.

20. The form of grain in use for the .236-inch small arm is the flat rectangular; for the .30-caliber Krag it is in the form of small short cylinders; for all other calibers the multi-perforated cylinder is at present employed, there being seven holes through each grain. Some powder for 1-, 3-, and 6-pounders has been in the form of thin ribbons about 2 inches long and ½ inch wide. The perforations of cylindrical grains are for the purpose of keeping the burning surface practically constant, thus securing the quality of progressiveness which is of prime importance.

21. When smokeless powder is employed in the form of a sphere or a cube, the cube burns smaller in all directions; consequently the surface upon which the flame is operating is rapidly diminished in all directions and the quantity of gas diminishes. If, however, the powder is formed in long strips, the amount burning from the ends is immaterial; consequently the reduction only takes place in one direction—that is, in the thickness, and therefore the reduction of the burning surface is much less rapid than in the case of spheres or cubes. For this reason powder that is formed in flat strips, or in long tubes, is more *progressive;* that is, it evolves equal quantities of gas in equal intervals of time. In the case of the multi-perforated grain, the burning surface decreases from the outside and increases from the inside. This form is, therefore, the most progressive of all.

NOTE.—Different forms of granulation have been advocated after a study of various erratic and disastrous ballistic results, the three principal forms being the *multi-perforated* grain with seven holes, the *tubular* or macaroni form and the *strip*. Experiment at the proving-ground will doubtless solve the problem as to the best form of grain for use in the navy.

22. General characteristics.—Navy smokeless powder is translucent and varies in color from a light lemon to a deep brown, almost black. These variations in color depend generally upon variations in the process of manufacture, and possibly upon the water used. The material possesses a marked degree of toughness, which operates to render the powder regular and progressive in action and prevents the unconsumed portion of the charge

from crumbling or disintegrating in the gun, under the influences of heat and gas-pressure due to those portions of the charge already consumed.

23. Drying the powder is accomplished in buildings fitted with trays with wire-net bottoms, air being admitted underneath the trays; or the powder is placed in large bins through which warm air is forced by blowers. For powder of the large calibers five or six months are required to dry out the solvent down to 3.5 per-cent. It is extremely difficult to reduce the volatiles to a lower point in thick-walled grains; in powders for the minor caliber guns the volatiles are reduced to about 2 per-cent in a month or six weeks of drying.

24. The diameter of the grain is reduced about one-third and the length shortened one-tenth as a result of the drying. After tests have shown the powder to be dry enough, it is carefully blended and then packed in air-tight cases ready for shipment and proof.

25. Ballistics of smokeless powder.—An example of the ballistic value of smokeless powder is shown in the fact that in a 6-inch, 40-caliber gun, 20 pounds of navy smokeless give a velocity of 2000 f. s. with 10.8 tons pressure, whereas 45.5 pounds of brown powder are required to produce the same velocity, while the resulting pressure is 15 tons. With brown powder, 2100 f. s. is the greatest velocity obtainable in the 6-inch, 35-caliber gun, while the smokeless easily produces a velocity of 2300 f. s. with less pressure and a charge weighing 25 pounds. The 12-inch, 35-caliber gun gives a velocity of 2100 f. s. using 425 pounds of brown powder. Exactly half this weight of smokeless will produce the same velocity.

26. In general, the new type large-chambered guns of 40- and 50-calibers length require a charge of smokeless weighing about 40 per-cent of the weight of the projectile. In the 12-inch, 40-caliber gun this charge gives a velocity of 2800 f. s.; in the 6-inch, 50-caliber gun the velocity for such a charge is 2900 f. s. These velocities would be impossible with black or brown powder.

27. It is certain that the powder is absolutely progressive in its burning. When small charges are used with consequent low pressures and rates of burning, it frequently happens that par-

tially burned grains are recovered in front of the muzzle of the gun. In all cases it has been observed that the outside diameter has been reduced and the inside diameter of the perforations increased in exactly equal amounts. The walls may be reduced to the thinness of paper, but the general structure of the grain remains intact.

28. Ignition charges.—Smokeless powder ignites at a temperature of about 180 degrees C. and black powder at a temperature considerably higher; nevertheless, the latter is very much more *inflammable* than the former, and a small quantity of it must be used as an *ignition charge.*

29. The question of ignition is an extremely important one in modern guns. Owing to the great length of the powder-chamber, inferior ignition will result in having only a portion of the charge ignited, with the result that the gases will be given off from that vicinity and will then expand to the opposite extremity of the chamber with great velocity and *add their dynamic effect to what should be only a static pressure.*

30. Wave-pressures.—The hurling back and forth of the gases constitutes what is known as " wave-pressures," and if the ignition of the entire charge is delayed until the shell has moved forward to a considerable distance in the gun, the result may be a high pressure at a point in the bore of the gun where the metal is not thick enough to withstand such pressure. It is a phenomenon similar to the " water-hammer " in hydraulic pipes.

31. To avoid wave-pressures, the entire chamber should be filled instantaneously with a burst of flame sufficient to ignite the whole charge; and the only way of accomplishing this, is by the use of a considerable quantity of highly inflammable powder (ignition charge) properly placed in the charge of smokeless.

Nitro-Glycerine Powders.

32. There are practically but two kinds of smokeless powder in use to-day, the powder described above and which is classed as a *gun-cotton powder,* and another class known as *nitro-glycerine powder,* which is made of a mixture of gun-cotton and nitro-glycerine.

33. Cordite and ballistite are the two best-known examples of nitro-glycerine powders. The former consists of a mixture of 58 parts of nitro-glycerine, 37 parts of tri-nitro cellulose, and 5 parts of vaseline. Acetone is used as a solvent, and the resulting composition, after the acetone is evaporated out, has the consistency of very hard beeswax and varies in color from a dark yellow to brown. *Ballistite* is very much the same kind of powder. The action of cordite, as compared with gun-cotton powder, is very brusque, hence, the powder is pressed out into solid cords and the charge is made up of bundles of these cords. By this means, the ratio of burning surface to weight of powder is less than it would be were the grains provided with longitudinal perforations; but this entails the loss of the quality of *progressiveness* which obtains with a multi-perforated grain. Hence, guns using cordite cannot attain the high muzzle velocity that can be had with gun-cotton powders.

34. Advantages and disadvantages of nitro-glycerine powder.—Cordite possesses a considerable advantage in that a very much lighter charge is required for *ordinary velocities* than is required with gun-cotton powder. Besides this, its form admits of the grains or cords being arranged in a uniform way in making up the charge, which, other things being equal, would give more uniform ballistics. It is, however, extremely sensitive to heat and cold, the velocity dropping with its temperature, and its pressure rising under the reverse condition. A very strong objection to its use lies in the fact that the rifling is rapidly eroded, causing an increasing and permanent loss of velocity that finally compels the relining of the gun. One more objection obtains with nitro-glycerine powder, and that is, that the nitro-glycerine exudes, or evaporates out, and impregnates the powder bag; thus the danger from the free nitro-glycerine is added to the disadvantage of a powder with a decreasing velocity and variable pressure.

35. Powders of this class have been made with only 25 per-cent of nitro-glycerine. They were brittle, and gave very erratic and sometimes disastrous results, and in general have been abandoned, although the great consideration of reducing the weight of the charge for field-guns has led to further experiments.

36. Erosion.—Erosion of the bore seems to depend upon the amount of heat imparted to the metal. As might be expected, when the work is so largely increased, smokeless powders raise the temperature of the gun to a much higher point than do black or brown powders. As has been stated, *nitro-glycerine powders are very objectionable in this respect,* and in the thinner-walled guns where the firing is very rapid and sustained, considerable erosion takes place even with the navy smokeless powder.

37. Special gas-checks have been devised abroad, which prevent the escape of the gases beyond the rotating-band of the projectile. This of course preserves the uniformity of the velocity within limits, but does not prevent the ultimate erosion and consequent disabling of the gun.

38. Disadvantage of gun-cotton powder.—Against the gun-cotton powders must be reckoned the disadvantage of leaving in the gun after discharge, a large amount of CO, *a gas which is both poisonous and inflammable.*

39. This is due to the *insufficiency of oxygen* contained in the gun-cotton to unite with the carbon and form CO_2 upon the rearrangement of the molecules. In the earlier powders, barium nitrate was mixed with the colloid in order to provide more oxygen; but it resulted in having a less reliable and less regular powder and was abandoned. Nitro-glycerine powders, being made of gun-cotton much higher in oxygen and the nitro-glycerine itself having a very high percentage of oxygen, this fault obtains to a very much less degree than in simple gun-cotton powders.

NOTE.—Notwithstanding this disadvantage of gun-cotton powder as compared with nitro-glycerine powders, it is almost universally admitted that the disadvantages of the latter (especially as regards erosion) are far more serious, and that none but pure nitro-cellulose powders are desirable.

40. The flareback is a name that has been given to the burning of the residual gas in the gun when the breech is opened after firing. Two things are necessary to cause a flareback—a fresh accession of oxygen from the atmosphere and a spark or degree of temperature high enough to unite the oxygen with the CO. Opening the breech will permit the necessary current of air to

mix with the CO and the spark may be easily supplied by a smouldering particle of powder-bag remaining in the bore.

Pressures, Velocities, Stability, Etc.

41. Pressures and velocities.—Both the pressure and velocity vary directly with the weight of charge, when the charge is not too small to prevent sufficient pressure being developed to burn up all of the grains before the shell leaves the bore, or, when the charge is not so large as to give pressures exceeding 17 or 18 tons. At that point there seems to be a deflection in the pressure curve, and a small increase in the charge may produce a very great pressure. The residual volatiles contained in the smokeless powder act as a deterrent, and if they are permitted to escape after the powder has been proved and a charge assigned, excessive pressures will result. It is, therefore, of great importance that the charges be always kept hermetically sealed; and conversely, it is necessary to protect the powder from the deposition of moisture on its surface or it will become "slower" and fail to give the designed velocity.

42. Stability.—Certain tests for the stability of nitro-cellulose powders are given which depend upon the fact that decomposing powder evolves the fumes of nitrous acid. In these tests the powder is heated above the atmospheric temperature to a point where all powders, no matter how stable, would eventually decompose. The *time* between the beginning of the heating and the appearance of the first signs of decomposition is taken as a measure of the stability. Instability is generally caused by insufficient purification of the gun-cotton of which the powder is made; but subjecting the powder to direct sunlight, or permitting it to sustain an abnormally high temperature for a protracted period will cause any powder to decompose.

43. Effect of instability on pressure.—Instability does not manifest itself in *higher pressures* in the gun. On the contrary one would look for *lower pressures* in a powder that had lost considerable oxygen and nitrogen. A strong odor of ether in the charge is often erroneously taken as an indication of decomposition. But it may be of no importance whatever, as a very minute

quantity of ether is sufficient to strongly impregnate the atmosphere of a large room.

44. Tests for stability.—In making the tests for stability, it is necessary to observe such directions as are given, with the greatest care and accuracy. All of the tests now known are entirely empirical and if the standard method is departed from in the slightest particular the value of the test is nullified.

NOTES ON U. S. NAVY SMOKELESS POWDER.

Compiled by LIEUT.-COMDR. A. C. DIEFFENBACH, U. S. Navy, in charge of proving-ground and powder factory, Dec., 1904.

1. Powder factories.—U. S. Navy smokeless powders are made by four private powder factories, by the Naval Powder Factory at Indian Head, Md., and, until recently, by the Naval Torpedo Station.

2. Variation in color, etc.—(1) Owing to various causes, such as mineral salts in the water used in the manufacture, peculiarities of the raw material containing the cellulose, etc., the powders made by these various manufacturers have distinctive and different appearances, some being dark and opaque, and others light and translucent.

(2) Again, a number of the earlier powders contained oxygen-giving salts such as potassium and barium nitrate. These powders have a reddish, murky, opaque appearance which is sometimes alarming. Index S. P. 14 was a case in point.

(3) Further, the process of "water drying," that is separating the excess of solvent under warm water, renders powder whitish and opaque, a very sickly color, which may give the powder the appearance of being in an advanced stage of decomposition.

(4) It would be well for officers to familiarize themselves with the appearance of the various kinds of good powders, because it has sometimes happened that a perfectly good powder has been considered bad owing to its peculiar appearance.

3. Packing.—In order that uniformity shall exist in the matter of volatiles, which includes also surface moisture collected in

packing or in exposure during packing, the packing is directed to be done in dry weather. The exposure, and the time consumed in packing, are required to be about the same for all manufacturers, and the *firing sample* is selected at the middle of the time interval. The powder is packed in air-tight boxes.

4. The firing sample is then sent to the Naval Proving-Ground where it is fired at a temperature as nearly as possible simulating the conditions of a hot magazine on board ship, namely, between 90° and 95° Fahrenheit. A laboratory sample is taken and enclosed in an air-tight bottle during the firing and sent to the laboratory for analysis.

5. The test-sheet.—The ballistic result, together with the accurate measurements of the dimensions of the grain, the consideration of the weight of charge required to produce the ballistic result in velocity and pressure, the residual volatiles, and the general character of the analysis of the powder determine its suitability for the gun. A *test-sheet*, as it is called, is then made out, containing all these data and forwarded to the Bureau of Ordnance, which then assigns the charge and index number to the powder, together with directions for its shipment to the magazines for distribution to the fleet.

6. Tests for stability.—The navy still retains the potassium-iodide-paper test, known as the heat-test, and which, from experience in the laboratory at the proving ground, has been demonstrated to be as good, if not better, than any other; and this test, together with the litmus- and volatile-test, constitute the principal chemical criteria of both new and suspected powders.

7. Dangerous powders.—The purity of nitro-cellulose from which the powder was made, and the residual volatiles, play the two important parts in the non-deterioration of the powder. It may be stated that from these two features spring the two kinds of dangerous powder which may be designated as *statically* dangerous and *dynamically* dangerous, and, curiously enough, the quantity of volatiles, or the amount of dryness at which the powder was issued, plays part in both of these.

8. (1) **A statically dangerous powder** may or may not become a dynamically dangerous one; but it is not probable, and it may, therefore, be considered alone as statically dangerous, giving

off nitrous-oxide gases, the cause of deterioration being due to lack of purification or to chemical changes through exposure to heat, etc.

(2) *The part the volatiles play* in this decomposition is a reflex one. If the powder has a tendency to decompose, the dryness of the powder aids. As decomposition goes on, the residual volatiles are absorbed in uniting with the nitrous-oxide gases, and if the rate of giving off gases is greater than the rate at which the powder can supply volatiles, the evolution of heat is an increasing one. In other words, *loss of volatiles alone renders a powder dynamically dangerous* by drying out the powder. Decomposition may or may not be accompanied by loss of volatiles. It is the giving off of this heat which renders the powder dangerous, from the fact that the process may be so rapid and the radiation of the heat so slow that the ignition-point of the powder (which is in good powders from about 350° F. to 380° F., and in decomposing powder may go as low as 250° F.) may be reached.

(3) *Statically dangerous powders may be discovered: First,* by the heat-test; *second,* by acid reaction on litmus-paper; *third,* by smell, which should be the acrid nitrous-fumes smell. Deterioration is an evidence of the loss of explosive properties, and some statically dangerous powders will not become dynamically dangerous but the very reverse—innocuous.

(4) If the decomposition has proceeded so far that nitrous fumes can be unmistakably smelled, condemnation should not be delayed.

(5) *Nitrous odors or visible red fumes* indicate a stage of decomposition greatly more advanced than the early indications shown by a low-heat test.

(6) It is known from experience that small-caliber powders are more prone to decomposition than the larger ones, due primarily to the larger percentages of volatiles in the large calibers; and yet an instance was reported from a magazine on shore where Index S. P. 9 and Index S. P. 19, 1-pounder and 3-inch powders, first developed their nitrous odors about five months after the detection of a low-heat test.

(7) It is the opinion of the chemist at the laboratory at Indian Head that in case a powder which has been regularly and periodically examined on board ship is suspected of deterioration, it does not become so rapidly dangerous that it need be condemned at once. Nevertheless, precautions should be taken and all directions as to the safety of the ship should be carried out. It is furthermore believed that in the event of a ship being in a position, such that it would be inadvisable to get rid of the powder entirely, a check to this deterioration can be given by cooling the powder in its air-tight cans, allowing none of the volatiles to escape. Of course, the first opportunity should be taken to forward a sample to the proving-ground for analysis.

9. (1) **The dynamically dangerous powder,** on the other hand, is one that is very seldom statically dangerous, being merely so from the fact that it is drying out and thereby becoming more violent.

(2) *The condition of dynamically dangerous powders* may be found in several ways. *First,* by an increase in muzzle-velocity as shown in range; *second,* by the chamber-pressure obtained by the pressure-gauges; and *third,* the loss in weight of the charge, always provided the charge had been accurately weighed when first issued, and again when the test is made. In this connection, it is well to state that the charge of smokeless powder as designated by the Bureau of Ordnance means the smokeless powder alone, exclusive of the bag and ignition charge. Each ship should be provided with a set of accurate and repeatedly checked scales.

(3) *The dynamically dangerous powders are becoming less and less in number* from the fact that powders are issued in a drier condition now and are packed in good standard air-tight boxes for the magazines. Nevertheless, from experience it has been found that the curve, whose co-ordinates are (1) *time since manufacture* and (2) *percentage of volatiles* in the powder, resembles very strongly, if it is not exactly, a hyperbola approaching an asymptote. It seems to be borne out in practice that no powder, however old, is entirely devoid of volatiles. But from this fact, also, it must be remembered that powders will always dry out slightly after issue, however long they are kept. The

time for the issue of powders for service is so selected that the point of dryness is at a point of the curve where a further decrease is a minimum.

General Remarks.

10. Ordnance officers.—It would be a good idea for the ordnance officer of every ship to inform himself of the characteristics of the indices of powders he has on board, and particularly with regard to the chamber pressure obtained at the proving-ground when the charge was assigned, as the pressure, after all, is the main criterion as to violence.

11. Ignition and inflammation form very important features with smokeless powders, and this is directly dependent upon the character of the burning surface of the grains, and their contamination in this respect, whether by oil, moisture, grease, or other cause, should be most strictly avoided.

12. Traces of acid.—In the matter of test it has been found occasionally that an acid reaction, shown by litmus-paper, has been given in powders which afterwards prove to be good, for the reason that slight traces of acetic acid evolved by moisture and solvent (the latter escaping from the powder), together with cellulose material, such as excelsior used for distance-pieces, formed what might be called a small vinegar factory. The actual fact as to whether such is the case, or whether the powder is really, through deterioration, giving off nitrous acid, may be roughly determined by drying the powder in an exposed vessel at a temperature of about 100° Fahrenheit for about twenty-four hours and then making the litmus-test again.

13. Visual-test.—An attempt was made to substitute a visual self-registering test for the heat-test by the introduction of some dye, preferably ros-aniline, in the powder which, by fading out, should show the beginning of decomposition; but owing to the fact that various makes of powders, as stated at the beginning, have different colors and degrees of opaqueness, this test was abandoned.

14. Odor of fumes.—If the odor of ether-fumes is detected in the magazine it is an evidence that the volatiles are escaping

from the powder through leaky powder-tanks, and these should be found and the fault corrected and this powder watched for increase in pressure. The magazine should also be well ventilated on account of the inflammability of the ether-fumes.

15. Loss of volatiles.—It has been further demonstrated by experiment at the proving-ground that the loss in volatiles as determined by chemical analysis *is almost exactly shown by loss in weight* where the weight is accurately determined at both times. From this it would seem that, after more data has been secured, the connection between increase of velocity and loss of volatiles, may be discovered on board ship by weighing the charge, provided, as before that the charge was accurately weighed when issued.

16. Drying-out.—In the case of strongly suspected drying-out of powders, as indicated by loss of weight or otherwise, the Bureau of Ordnance should immediately be notified, in order that firing samples may be sent to the proving-ground for reassignment of charge.

17. Care in drying powders.—Where the powder, for any cause, requires to be dried or exposed to the air, the greatest care should be taken not to expose it to the direct rays of the sun for any length of time, as it is known that the actinic power of these rays exerts a deteriorating effect upon smokeless powder.

18. Altering charges.—It is believed that it is not wise with powders now on board ship to alter the charge there, not only for the reasons before given in regard to recently manufactured powders, but because all powders of earlier manufacture have had reassignments of charge of late.

19. Precaution and tests.—The subject of the tests of smokeless powder, its storage, and the ventilation of magazines is given in Special Order No. 39.

CHAPTER XXVII.

PRIMERS, EXPLODERS, CARTRIDGE-CASES, DISTANCE-PIECES, POWDER-BAGS, IGNITION-CHARGES, AMMUNITION-BOXES, AND POWDER-TANKS.

PREPARED BY ENSIGN HAROLD E. COOK; U. S. NAVY.

Primers.

1. The primer of any gun or firearm is the specially constructed device which, when exploded by the direct action of the firing-mechanism, ignites the powder-charge by its flame of discharge and fires the gun. The primer, for R. F. ammunition, is in the recess in the center of the base of the cartridge-case; for B. L. ammunition it is placed in the firing-lock and its flame travels through the mushroom-stem to the powder-charge. There are at present three varieties of primers in use: *percussion, electric,* and *combination* primers.

2. Percussion- and electric-primers are now supplied for B. L. Rs., a combination screw-primer for 6-inch R. F. guns, combination drive-primers for 3-inch, 4-inch, and 5-inch guns, and percussion-primers for all secondary guns.

3. Percussion-primers are those containing a sensitive explosive which is fired by the jar or friction resulting from the blow of the firing-pin or hammer. The explosive in commonest use is fulminate of mercury, which explodes by percussion, by friction, by the electric spark, by heating to about 300 degrees, or by contact with concentrated nitric or sulphuric acid. It is extremely sensitive, particularly when mixed with sand or ground-glass, and is very sudden in its action, though its explosive force is, weight for weight, not much greater than that of gunpowder. It is the best-known substance for detonating dry gun-cotton; equal

weights of much more violent explosives will, when substituted for it, often fail to produce an explosion of the first order. For use in primers, the fulminate is usually mixed with niter, mealed powder or other substances to moderate its explosive properties; and to increase its sensitiveness a small quantity of ground-glass is incorporated.

4. (1) **The primer-cap** used for service primers consists of a copper cup which is primed with the standard Berdan mixture, composed of fulminate of mercury, chlorate of potash, and ground-glass. The cup is loaded wet and a leaf of shellaced tin-foil is pressed on top of the priming-charge. The primer is then dried for a period of several weeks and a small anvil is put in place inside the cup. When the bottom of the cup is struck by the firing-point the fulminate is driven against the anvil and explodes by friction.

(2) The cap is "vent-sealing" and unless it is pierced by a too violent blow of the firing-point there will be no "blow-back" of gas.

5. Cartridges for small-arm ammunition simply have a Winchester cap for the primer.

6. The percussion-primer used in all 1-pdr., 3-pdr., and 6-pdr. ammunition is shown in Fig. 1, Plate I; the magazine contains 42 grains of powder and is closed by a paraffined paper wad.

7. The percussion-primer used for B. L. Rs. is shown in Fig. 4, Plate II. The cap (1) is held in the cup (2) which is held in place by the outer cup (3) and bolt (4). The outer cup is crimped in place. The anvil (5) has a thin shearing safety-collar (6) held by the ring (7). The head of the anvil has a nut (8) screwed on after the primer is assembled. The firing-pin drives the anvil forward, shearing the collar and exploding the cap, the flame passing through the vent to the magazine (9), which contains about 48 grains of black powder.

8. Friction-primers, still supplied in a few instances for the impulse charge of Whitehead torpedoes, were for a time used in B. L. guns as an alternative for the B. L. percussion-primers. They contain a roughened wire running through the fulminate and ending in a loop at the rear end; the firing-lanyard is attached

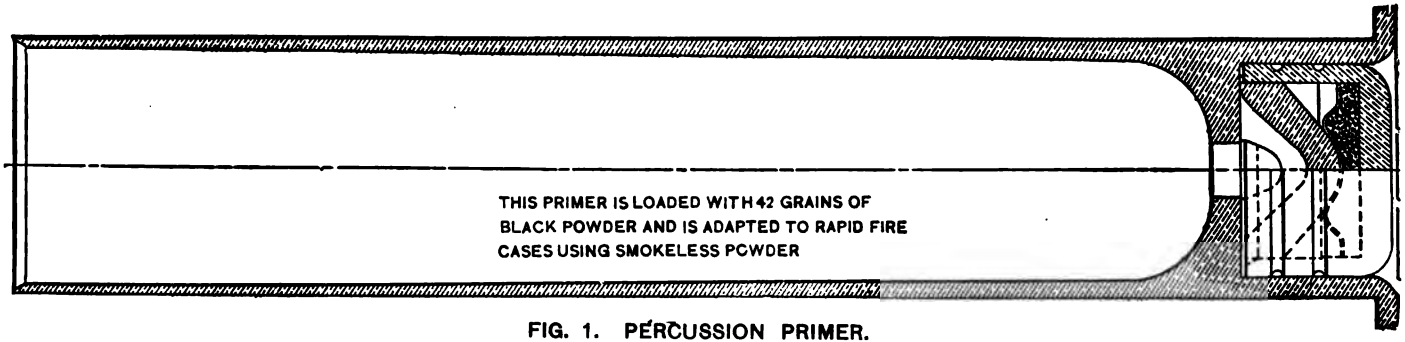


FIG. 1. PERCUSSION PRIMER.
For 1-3-6-pdr. and 3-inch field-gun cartridges.

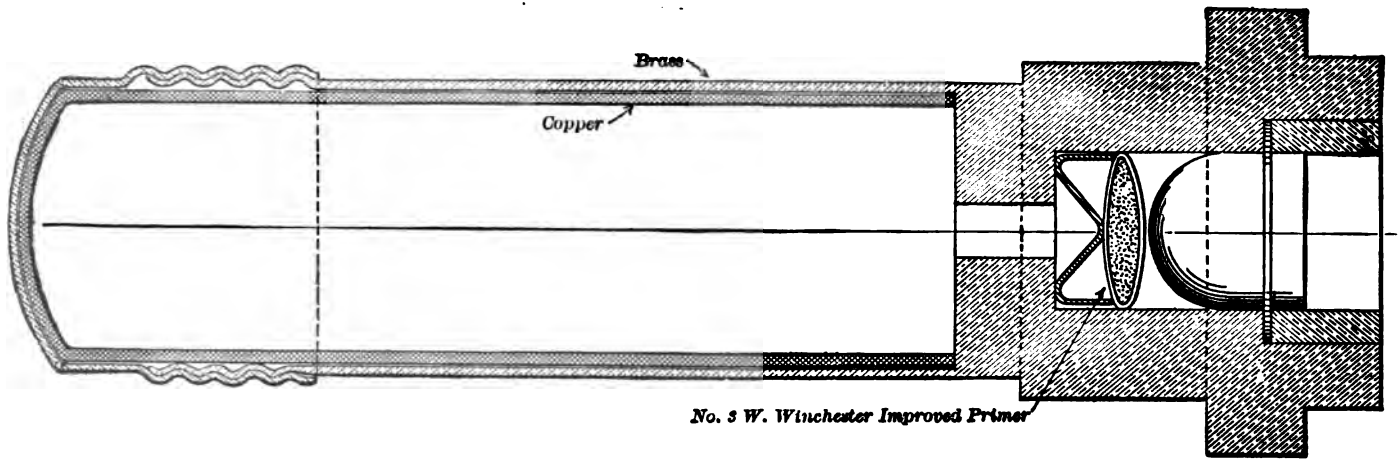


FIG. 2. EXPLODER FOR WHITEHEAD TORPEDO.

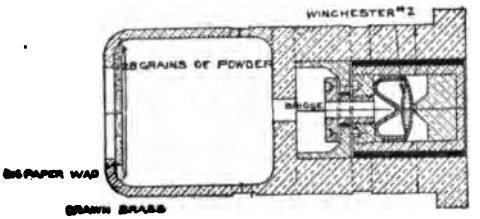


FIG. 1. COMB. PRIMER FOR 3, 4, AND 5-INCH CARTRIDGE CASE.

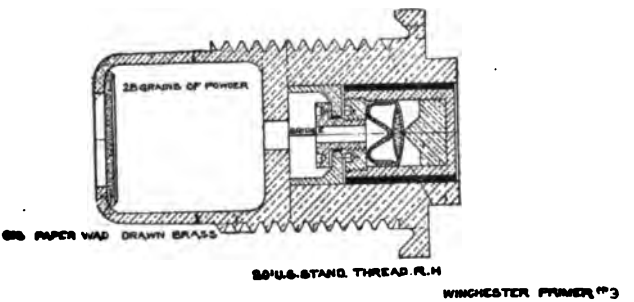


FIG. 2. COMB. PRIMER FOR 6-INCH CARTRIDGE CASE.

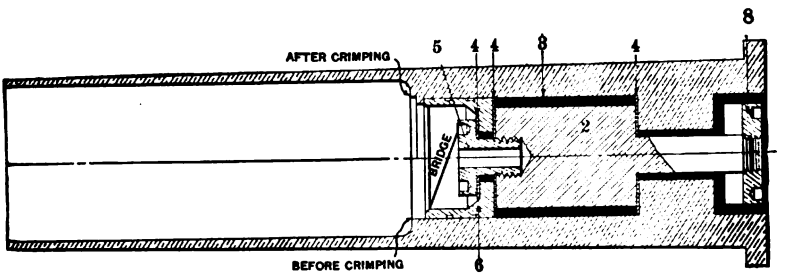


FIG. 3. B. L. R. ELECTRIC PRIMER, MARK VI.

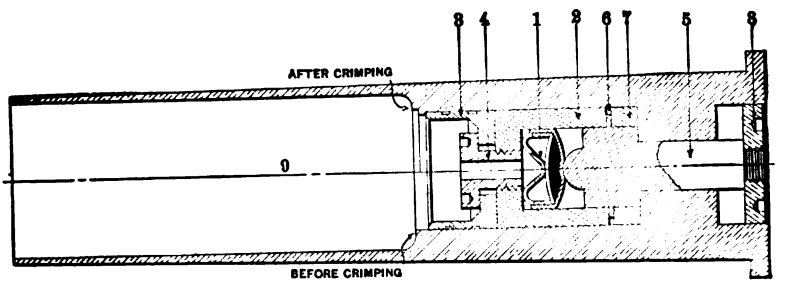


FIG. 4. B. L. R. PERCUSSION PRIMER MARK VII.

SERVICE PRIMERS.

to this loop, and, when it is sharply pulled, the roughened wire is drawn out, creating friction enough to explode the fulminate.

9. (1) **Electric-primers,** containing no fulminates, superseded the percussion-primers of main-battery guns, as being safer, more reliable in themselves, and because they materially reduced the firing interval.

(2) The latest form of B. L. R. electric-primer is shown in Fig. 3, Plate II. It resembles the B. L. R. percussion-primer previously described. The cup, cap, and anvil are replaced by a solid piece (2) held by the nut (8). All parts are insulated by the ebonite bushings (3) and mica washers (4). A bridge of wire composed of 90 per-cent platinum and 10 per-cent iridium connects the bolt (5) with the cup (6). The magazine contains 48 grains of black powder and the bridge is surrounded by a wisp of dry gun-cotton. The current through the firing-pin passes through the anvil-bolt and bridge to the cup, whence it grounds through the case to the gun.

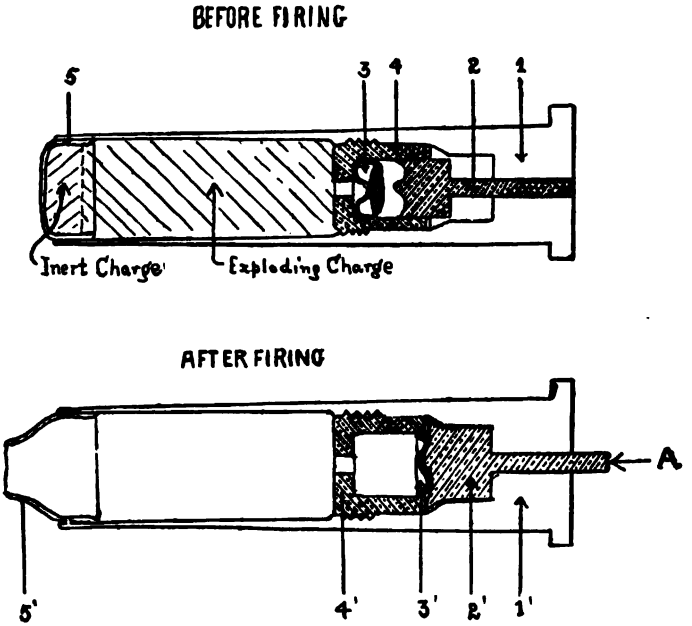
10. A combination primer is in itself an electric-primer and a percussion-primer, combining the functions of both in one case. As long as all the mechanism and attachments are intact these primers are used electrically, and the percussion feature is regarded only as an alternative; the firing-mechanisms, as we have seen, are arranged to work in either manner.

11. Combination primers are furnished for R. F. guns of the main battery, the different varieties as shown in Plate II. Fig. 1 is the R. F. "drive" primer for 3-inch, 4-inch, and 5-inch cartridge-cases, and Fig. 2 the R. F. "screw" primer for 6-inch cartridge-cases; the only difference between them is in the way of attaching them to the cases. The details are clearly shown and require no description if the principles of simple electric and percussion-primers are known; all of them are vent-sealing. When firing by percussion the cap is not directly struck by the firing-pin but by the point of a plunger forced inward by its blow.

12. These primers have given great satisfaction in service. It is to be kept in mind, however, that they contain fulminate, and the precautions needed in the use and handling of ordinary percussion-primers are called for, because of their sensitiveness to shock.

NOTE.—**Self-Recording Primers,** or primers that indicate their discharge.

(1) Many experiments have been carried out with the idea of developing a device, which, in the case of a miss-fire in a B. L. R., will indicate whether or not the primer has been fired. Most of the devices developed have depended upon the making or breaking of an electric circuit and operating a buzzer, bell, or light; but these have been unsatisfactory owing to the frail connections and complications.



THE MCNEELY-GRAEME SELF-RECORDING PRIMER

(2) The following is a brief description of a primer developed by Lieuts. R. W. McNeely and J. W. Graeme, U. S. N., which is a simplification of the present service B. L. R. percussion-primer and also indicates its discharge. It is shown in the figure. It consists of the following parts: case (1), anvil (2), cap (3), cup and nut combined (4), and sealing-cap (5), all parts being of tobin bronze.

(3) The action of the primer is as follows: When the anvil is driven forward by the firing-pin of the lock, exploding the cap, the sealing-cap (5) accumulates pressure before it bursts out, and the anvil is driven back against a slightly conical seat (which provides an efficient gas-check) beyond its original position, swelling out the lip of the anvil into the annular

slot, thus holding the anvil positively to the rear. The shank, *A*, of the anvil will then be visible, and at the same time forces the hammer of the firing-lock to the rear by the amount of recoil of anvil. This constitutes a visual signal. The wedge of the firing-lock is fitted with a vertical slot so that it may pass the recoiled end of the anvil during extraction.

(4) A mixture of magnesium and iron-filings is put just inside the sealing-cap, and this spreads, intensifies, and increases the range of the flame from the primer, insuring its contact with the scrim of the powder-bag.

(5) The electric and combination E. & P. primers are similar in construction.

(6) The strength of this primer-stock at the base has been increased very much by eliminating the large nut usually placed on primer-anvils to increase the surface for the percussion firing-pin and for making electric contact.

13. Exploders are the devices which detonate the gun-cotton charges of torpedoes—for Whitehead torpedoes, they correspond, perhaps, more nearly to *fuses* than to primers. The Whitehead exploder is shown in Fig. 2, Plate I; it is carried in the war-nose and is fired by percussion. When the torpedo strikes, the firing-pin of the war-nose drives in the small striker which is held in place ordinarily by a brittle shearing-pin as shown. This striker explodes a cap which in turn fires the 35 grains of fulminate in the attached copper magazine; the *dry* gun-cotton primer is detonated by the exploder and in turn detonates the main charge of *wet* gun-cotton in the warhead.

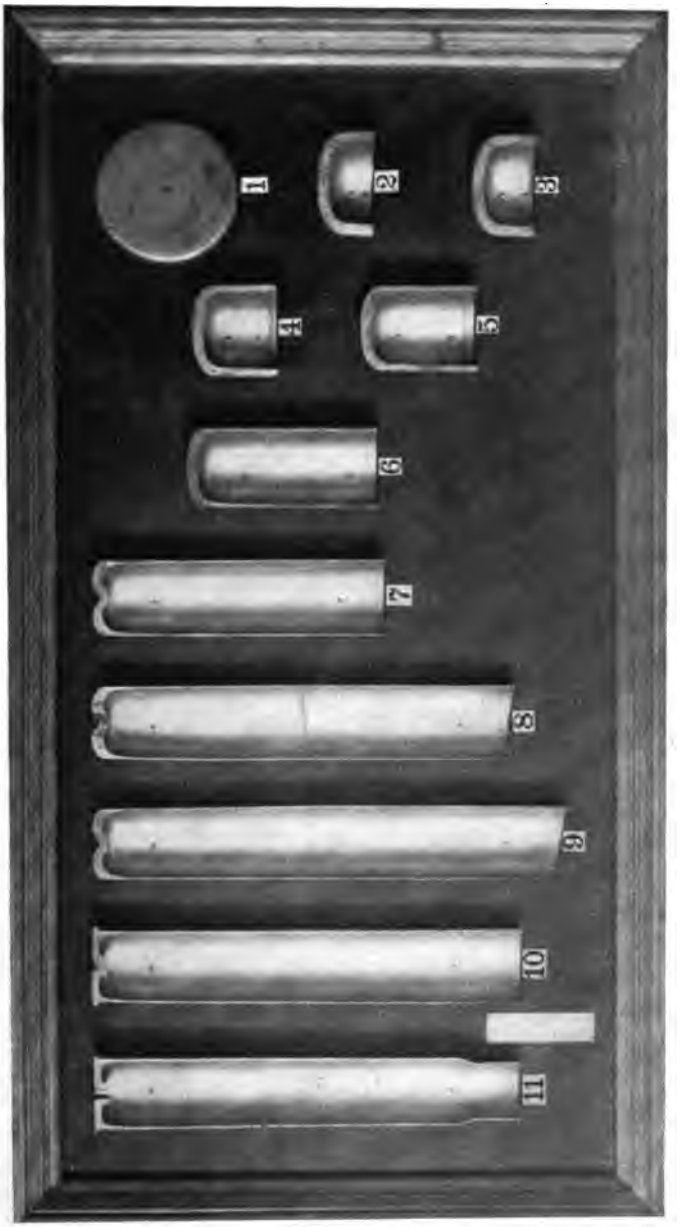
14. The exploder for the service gun-cotton mine is of the same size and shape as the above but is fired electrically. There are two leading wires from the firing-battery to the primer which, within the latter, are reduced to a thin bridge; the explosion is caused by heat as in the simple electric-primer.

Metallic Cartridge-Cases.

15. The powder-charge for all rapid-fire guns is put up in brass cartridge-cases which are hollow cylinders with flat heads, shaped to fit the bore, those for new guns being bottle-necked. The head has a rim for the extractor and a recess for the primer. They are made from solid discs and are drawn into shape in the successive processes described below. The metal used is a brass composed of 70 parts Calumet and Hecla copper and 30 parts

pure Bertha zinc. The metal produced by this mixture is very malleable and ductile, rolls well, and is of bright yellow color.

16. Manufacture.—The essential steps in the process are casting, rolling, blanking, cupping, drawing, indenting, heading, tapering, and finishing. These are shown in Plate III. After each of the above processes, except after the last tapering, the case is annealed to soften the metal and to remove strains set up during the process. It is not done after the last taper, because if done the metal would be soft in the finished case. The brass is mixed in crucibles and cast into slabs. There is much scrap used in the mixing, this scrap coming from the blanking, and from many imperfect cases which are cut up to be remelted. The slabs have their rough ends cut off and are then passed a number of times through heavy blanking-down rolls, to solidify the metal. They are then straightened in the rolls, scraped clean, given a bath in dilute sulphuric acid, and finished rolled. The slabs are then blanked out into circular discs (1, Plate III). Then comes the cupping and drawing. The cupping-press has a punch at the end of a ram which descends under a pressure of 1350 pounds per square inch, forcing the disc through a die and forming the cup (2). The metal is not drawn in the cupping—that is, its thickness is not changed, the edges being simply bent up, forming the cup. The drawing processes (3, 4, 5, 6, 8, 9) now begin. These consist in forcing the case successively through small dies, the punch increasing in size, thus decreasing the thickness of the metal by lengthening or drawing it out. Soapsuds are used freely in all these operations to lubricate and absorb the heat. After the cupping there are from five to eight draws, depending on the caliber. After the fourth or fifth draw the indenting (7) takes place. This machine puts a dent in the center of the head, thus raising a portion of the metal on the inside to provide a seat for the primer. The remaining drawing processes are then completed and the case is put in a lathe and cut off to the proper length for heading. This is done in a vertical press which has a ram which lifts the case, forcing the head against the heading die under very high pressure (over 2000 tons for 6-inch cases). The cases now go to the taper draw-presses and the bottle-neck is formed. After the second taper the case is put in a lathe, trued



STEPS IN MANUFACTURE OF CARTRIDGE-CASES.

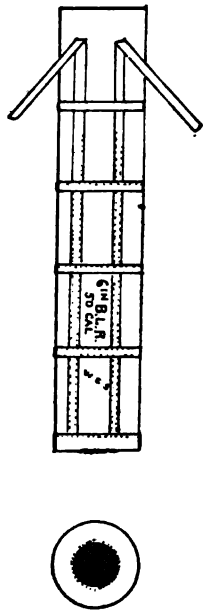


FIG. 1.
5-inch and 6-inch.

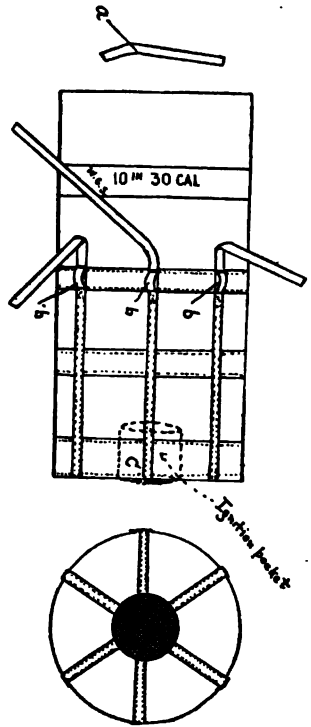


FIG. 2.
7-inch, 8-inch and 10-inch 30 cal.

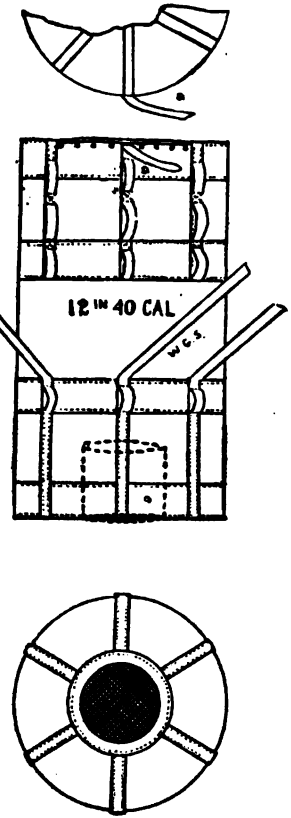
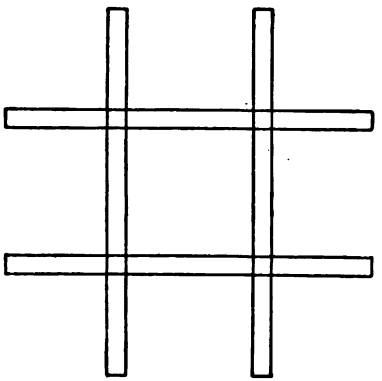


FIG. 3.
12-inch.

POWDER-BAGS.

up, cut off to the proper length, and the head, extractor-rim, and primer-recess are turned out. They are then gauged, inspected, and stamped with the date, number of the lot, and initials of the inspector.

17. Inspection.—All cases are gauged by the workmen in charge during each process. After a lot is reported ready the inspector picks about 4 per-cent of the lot and gauges them all and looks them over for flaws. There are nine sets of gauges (a maximum and a minimum) which check all surfaces and the mouth, extractor-rim, and primer-seat. After inspection a small



PASTEBOARD DISTANCE-PIECE. ART. 19.

number are sent to Indian Head for proof, and must be fired and reloaded six times in a service gun, without the use of a former, before the lot is accepted. The average life of a case is six firings, as after that the metal becomes fatigued and the case takes a permanent set. Empties are sent to some magazine, where they are reformed and reloaded in a press. Some cases have been fired between thirty and forty times without destroying their usefulness.

18. Fit of shell in cartridge-case.—The base of the shell should fit tightly and be perfectly secure in the cartridge-case in fixed ammunition. When the shell is loose there is danger and delay in loading, and the space in the cartridge-case being increased, the ignition-charge may work away from the primer and cause hang- or missfires.

19. Distance-pieces for cartridge-cases.—The space between the powder and the base of the shell in 3-inch, 4-inch, 5-inch, and 6-inch cartridge-cases was sometimes filled with excelsior. This made smoke and was objectionable. To replace the excelsior, *distance-pieces,* made by crossing and locking four pieces of pasteboard, are used. The distance-piece can be cut to any length desired. For minor calibers, tubes of pasteboard are used in some cases. These tubes are much smaller in diameter than the cartridge and are held between two wads of pasteboard.

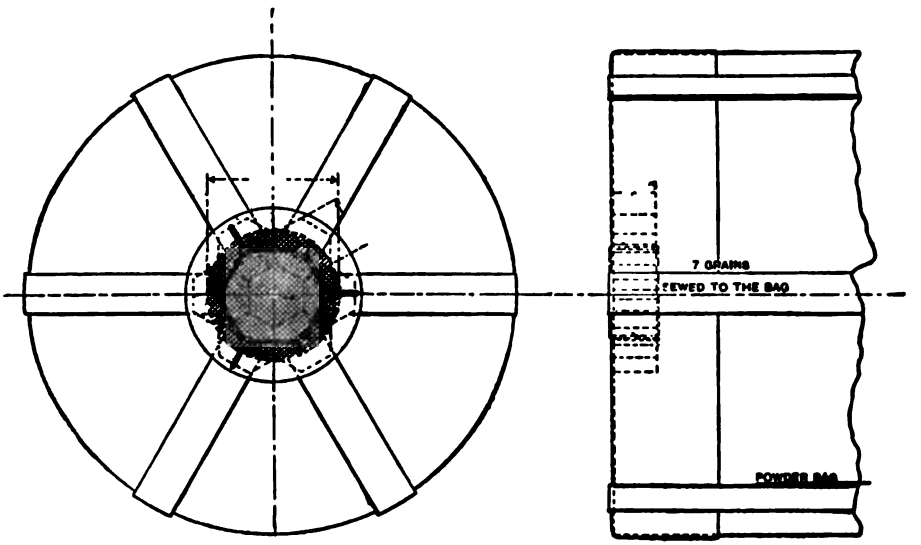
20. When the powder is confined in a bag the distance-piece extends from the tie-end of the bag to the base of the shell. When no bag is used a wad is placed over the powder and the distance-piece extends from the wad to the base of the shell, or to the cover of the metallic cartridge-case when the ammunition is "separate."

21. Powder-bags.—The principal forms of powder-bags now being used are shown in Plate IV. They are made of unbleached muslin, having a bottom of double thickness, and chafing-bands wherever there is a bend in the bag, and longitudinal bands, and circular bands of cotton-tape. The longitudinal strips usually have loose ends called "tie-ties" and used to secure the bag after it is filled. A large circular piece is cut out of the bottom and a double thickness of gauze is sewed in. This is to facilitate the passage of the flame from the primer to the ignition pocket, which is sewed in the bottom, and is called the "scrim."

22. Powder-bags are now used in making up the charges for metallic cartridge-cases down to and including the 3-inch field gun. These bags have a double thickness at the bottom with pancake ignition-pocket, but have no bands or tie-ties, and are simply tied up around the end after filling.

23. The powder-bag for 5-inch and 6-inch guns is shown in Fig. 1. There is a pancake ignition-pocket which is formed by the inner thickness of the bottom.

24. Two bags are used for a full charge in 7-inch, 8-inch, and 10-inch, 30-caliber, B. L. Rs., and the general form is shown in Fig. 2. There is a loop (*b*) for each "tie-tie" which forms a longitudinal strip to be secured to, and a separate piece of tape (*a*) is used to tie all the tie-ties together at the point where they cross



IGNITION-CHARGE, 10-INCH B. L. R.

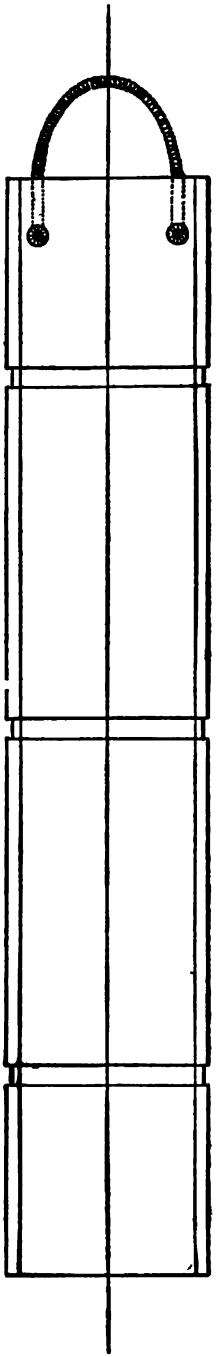


Fig. 1.

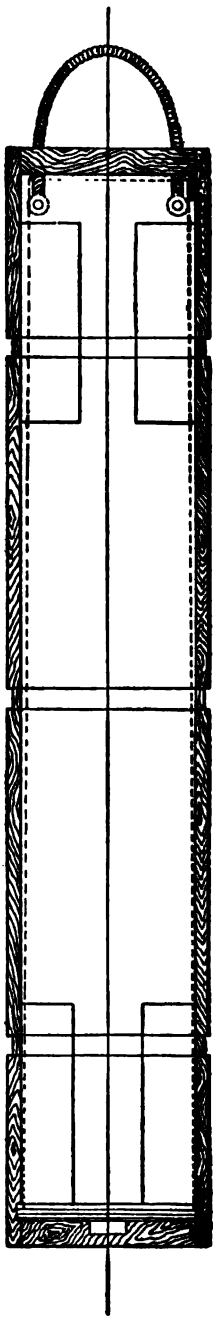


Fig. 2.

WOODEN FIXED-AMMUNITION BOX FOR 4-INCH AND 5-INCH AMMUNITION.

over the end. The ignition-pocket is a small bag (*c*), and after it is filled the end is tied.

25. A new form of bag for 8-inch guns has cross tie-ties which tie along the side.

26. The bag for the new 10-inch, 45-caliber, gun will be similar to the 12-inch bag.

27. Four bags are used for a full charge for 12-inch and 13-inch guns, and the form of bag is shown in Fig. 3. It has both top and bottom of double thickness. There are six tie-ties at each end with ends in the middle on one side and loops on the other, so that the bag can be used either for full or reduced charge. The top has an opening in the circumference of about 120 degrees for filling the bag ignition-pocket (*c*) and is laced up through eight cotton-bound eyelet holes and has the tie-tie (*a-a*) also.

28. Powder-bags are marked with the gun and caliber, the kind of charge, index number of powder, and initials of the inspector.

29. ***It is most important that the bags should be stiff and that they should fit the chamber.*** The powder should be well shaken down and the bag tied tightly above the powder, extra material being cut off the tie-end.

30. Charges which are flabby, or loosely put up, cause trouble and serious delay in loading. For this reason it is well to examine, and, if necessary, re-tie charges before sending them up. This precaution may be taken in anticipation of target practice or active service.

31. Ignition charges for large caliber powder-bags.—The ignition charge for 7-inch, 8-inch, 10-inch, and 12-inch charges consists of seven grains of black prismatic powder cemented together with a thick solution of shellac and alcohol, and placed upon the scrim at the bottom of the bag and inside a small cylindrical pocket which is sewed to the bag around the scrim on the inside. The mouth of the pocket is then secured, thus holding the ignition grains close against the scrim in the center of the bottom. The powder is then poured in on top of the ignition charge, shaken down well, and the bag tied tightly. (Plate V.)

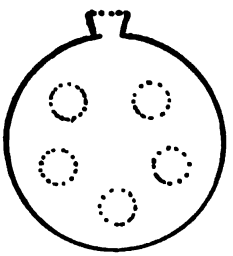
32. Pancake ignition-pocket for small caliber powder-bags.—For powder bags of 3-inch, 4-inch, 5-inch, and 6-inch guns, a flat

circular pocket of muslin with a filling hole for small-grained black powder, is sewed to the bottom of the bag on the inside close against the scrim.

33. In order to keep the pocket flat and prevent the powder from falling down to one side away from the central line, five small circles are stitched through the pocket as shown in the sketch.

34. The ignition-pocket is filled with fine-grained black powder as follows: 4-inch, 40 grammes; 5-inch, 60 grammes; 6-inch, 100 grammes.

35. The flame from the primer passes through the scrim in the bottom of the bag, penetrates the ignition-pocket, and ignites the



PANCAKE IGNITION-POCKET. ART. 32.

black powder, which in turn ignites the smokeless powder which is poured in on the top of the pocket. It is important that the powder should be well shaken down and the bag tied tightly.

36. Fixed-ammunition boxes.—(1) For the 4-inch and 5-inch R. F. guns each round is in a box by itself. The boxes are made of poplar wood with a becket at one end, the cartridge being held by corner wedges, and one side of the box being easily removed by cutting the three lashings which hold it in place, as shown in Plate VI.

(2) These boxes are painted to indicate the character of the projectile, as follows:

Armor-piercing .....All black.
Steel, common .....All lead color.
Shrapnel .....All white.

Boxes for drill cartridges are half white and half black.

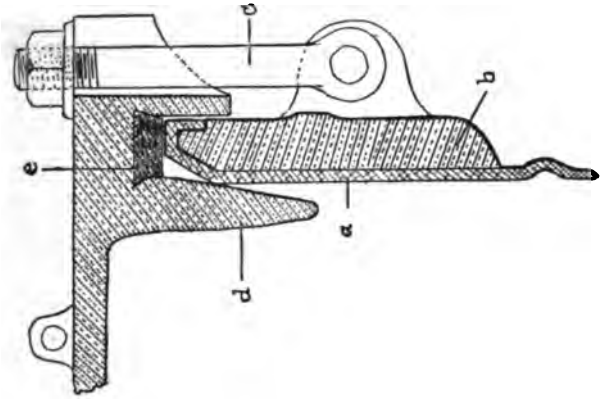


FIG. 3.—12-INCH TANK.

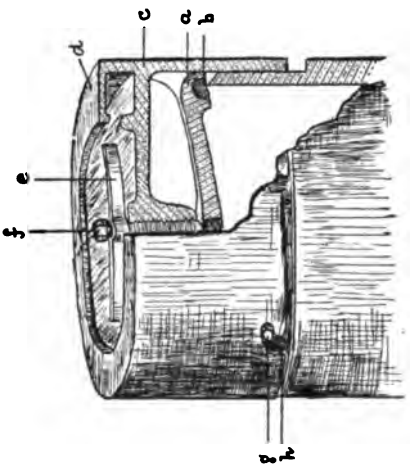


FIG. 2.—6-INCH TANK, MARK VII.

POWDER-TANKS.

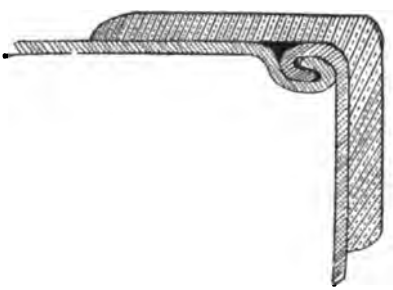


FIG. 1.—BOTTOM OF TANK.

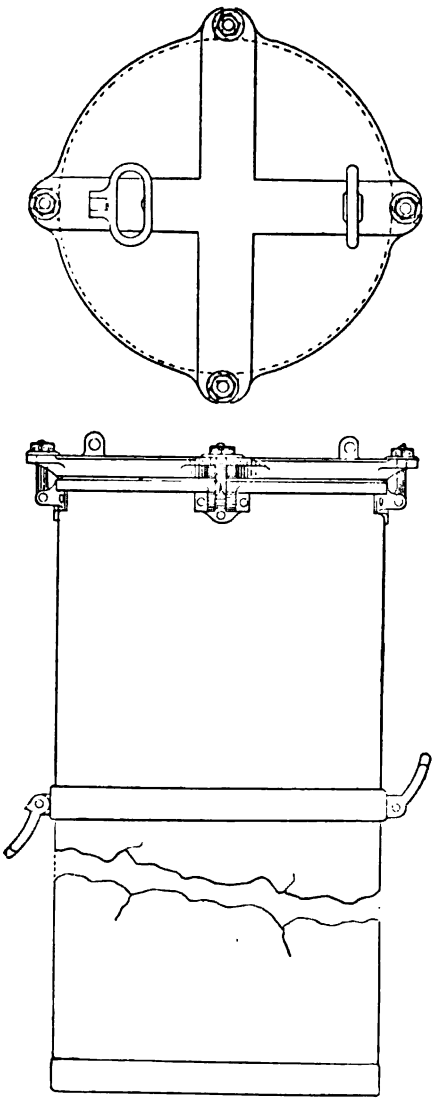


FIG. 1.

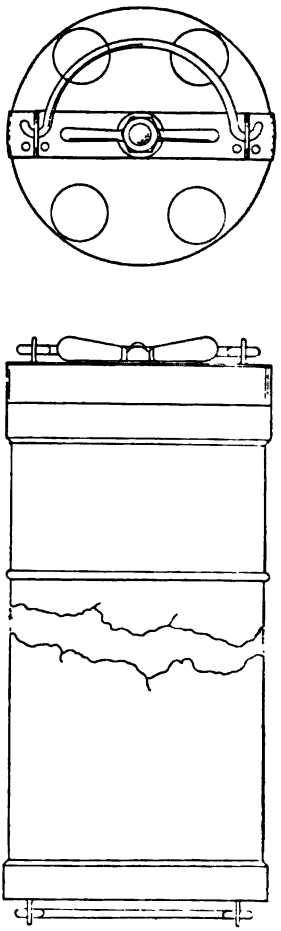


FIG. 2.

OLD FORMS OF POWDER-TANKS.

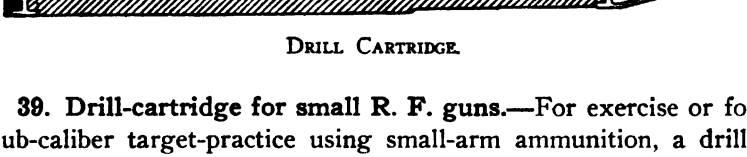
37. Fixed-ammunition boxes for minor calibers.—The fixed ammunition for R. F. guns of minor caliber is placed in chests, the number of rounds for each being as follows:

1-pounder (light and heavy)	60	rounds.
3-pounder	16	"
6-pounder	11	"
3-inch field gun	17	"
3-inch field gun (new)	8	"
3-inch, 50-caliber, R. F.	4	"

38. These chests are painted as follows:

Armor-piercing	Black, white letters.
Steel, common	Lead, red letters.
Cast-iron, common	Red, black letters.
Shrapnel	White, black letters.
Saluting charges	Half white, half red.
Blind shell	Half black, half red.

Blind 3-inch, 4-inch, and 5-inch boxes, red band 12 inches deep at each end and both ends red.



DRILL CARTRIDGE.

39. Drill-cartridge for small R. F. guns.—For exercise or for sub-caliber target-practice using small-arm ammunition, a drill-cartridge of the same general shape as the regular cartridge is provided. It has a metallic base and point, and in the axis a short length of a rifle barrel, caliber .45, is inserted. The body of the drill-cartridge is a hard, close-grained wood.

40. Drill-cartridges are packed in chests painted half black and half white, the dividing plane being parallel to the ends of the chests.

41. Drill-cartridges for 4-inch and 5-inch R. F. guns are the same in shape and size as the regular complete cartridge, and similar in design to those for the secondary battery, with the same provisions for sub-caliber practice with .45-caliber ammunition.

42. The drill-charge for B. L. Rs. is composed of small blocks of wood the size of grains and the bag is made of canvas, and the whole is made as nearly as possible like the actual charge in weight and size.

43. Powder-tanks.—Powder-charges for B. L. Rs. are stowed in copper tanks. These tanks should be as strong and at the same time as light as possible for handling. They should be made to open quickly and must be perfectly airtight, as the ballistic properties of smokeless powder change on being exposed to the air. As it has been found difficult to fulfil all these conditions, many types of tanks have resulted, and the latest are described below.

44. The general form is a cylindrical copper tank with edges crimped, and a copper bottom is bent on, forming a double-soldered joint, as shown in Plate VII, Fig. 1. At top and bottom are brass strengthening-rings. The tanks are protected by vertical wooden battens held in place around the tank by three copper bands. Handles of brass are riveted to the sides of the tank for handling. All joints are soldered.

45. Tanks for 5-inch and 6-inch charges are similar to that shown in Fig. 2. There is an inner cover (*a*) which has a circular groove filled with a lead joint or leather gasket (*b*). An outer cover (*c*) fits over the top strengthening-ring with bayonet-joints (*g*) fitting over pins (*h*). This cover has a raised rim (*d*) which protects the wing-nut (*e*). When the outer cover is put in place the inner cover is screwed down tight on its joint by the wing-nut (*e*) working on the screw-spindle (*f*).

46. Tanks for 7-inch, 8-inch, and 10-inch charges are similar to Fig. 2, with slight variations in the covers.

47. The latest form of tank for 12-inch and 13-inch charges has a cover which is held down by four bolts (*c*) as shown in Fig. 3. The copper of the tank (*a*) is carried up over the top of the ring (*b*) making the joint. The cover has an inner strengthening-rib (*d*) and has a circular groove in which is placed a leather gasket (*e*) which has been thoroughly impregnated with petrolatum.

48. Old forms of tanks had covers which were held down by four bolts against a rubber gasket, but these did not remain air-

tight, as the rubber dried due to the heat in the magazines. (Plate VIII.)

49. A recent form of 12-inch and 13-inch tank has eight bolts and the joint was made metallic and ground in, but this was objectionable, as it occasioned loss of time.

50. All new tanks will have leather gasket and joint as shown in Fig. 3, Plate VII. Those up to and including 8-inch will have covers similar to that shown in Fig. 2; those for 10-inch, 12-inch, and 13-inch will be similar to that shown in Fig. 3.

51. All tanks when finished are set up tight and are put in a large tank filled with water, and must stand a pressure of 5 pounds per square inch without leaking.

CHAPTER XXVIII.

PROJECTILES.

REVISED BY LIEUTENANT JOHN HALLIGAN, U. S. NAVY.

1. Manufacture of armor-piercing projectiles.—Material selected for the melting operation is first prepared in convenient size to be shaken in a plumbago crucible which has a capacity of about 90 pounds of steel contents and weighs in itself about 30 pounds. The melting furnace is of the Siemens gas-regenerative type, with a capacity of 30 to 48 or more pots, in several holes, each of the latter holding six pots.

2. The filled pots are lowered at one time by means of hand-tongs into the melting-holes and in about four hours are ready to teem or pour. The molds are of cast-iron and are cylindrical in form, being split in two lengthwise, and the bottom of the mold following generally the curvature of the shell-point; the extreme point end being continued in a square projection, which later serves as a hold for the tongs in the hammer forgings.

3. The pots are pulled out of the furnace by means of hand-tongs and the fluid steel surface is carefully mopped to remove floating impurities; then, by means of other hand-tongs, the teeming is accomplished by pouring pot after pot slowly into the top of the prepared mold, the stream of molten steel never being allowed to stop for an instant until the proper weight of steel to make the required ingot is contained in the mold.

4. When the steel has solidified, and before losing its heat, the rings are stripped from the mold and the red-hot ingot is exposed and at once removed to the reheating furnace (coal-fired reverberatory), near the forging-hammer. The latter is of the ordinary type of steam-hammer and has a striking blow of 16 tons.

5. The forging dies are formed to follow the curves desired in the finished shell, and the ingot is given a uniform reduction therein so that the forging, as completed, is from ½ to ¾ inch larger in diameter dimensions than is required in the finished shell.

6. An annealing treatment next follows to take out all hammer stresses and to reduce the steel to a suitable condition for machining; this annealing operation requires about a week, after which the forgings are removed to the machine shop and after being centered in a special machine are chucked in a special turning machine and the outside metal removed; leaving the shell surface finished completely, with the exception of the swell of the point (the bourrelet), which is left full.

7. The shell is now removed to the cutting-off machine, where the top of the ingot is cut off and the serial number is transferred to the band-score.

8. The shells are next chucked in a special machine and the boring out of the chamber cavity accomplished.

9. After cutting the score for the cap on another special machine, the shell is ready for the hardening process, which is secret.

10. In the meantime the steel for the base-plug has been cast and forged into round bars, which are cut into blanks, and these later threaded and finished in turret lathes, the finished plugs awaiting the hardened shells.

11. Ballistic selection is made by the inspector from the completed lots as they come from the hardening operation, and after the Bureau has signified its acceptance, the shells are machined to receive the base-plug, the base receives its markings with steel stamps, the shell is ground on its bourrelet to within specified tolerances, the copper band is hammered and pressed into the band-score, and the shell again chucked in the lathe for turning the band. The hydraulic press then secures the soft steel cap to the point of the shell and completed lots are given the official inspection and stamped with the accepted stamp, after which all that remains is to box and load in cars for shipment.

12. The copper for bands and bronze for fuse-plugs are prepared elsewhere, and so is generally the soft cap, these being furnished the manufacturers.

13. **A. P. Shell.**

	6-in. lbs.	7-in. lbs.	8-in. lbs.	10-in. lbs.	12-in. lbs.	13-in. lbs.
Weight complete	105	165	260	510	870	1130
Weight of bursting-charge	2.0	3.23	5.8	9.75	18.18	22.11

Specifications for Armor-Piercing Shell for the United States Navy.

14. (1) Shell will be made in strict accordance with the Bureau's drawings, working within the latitude and tolerances shown thereon.

(2) The shell must be of domestic manufacture and must be finished to the dimensions shown on the drawings approved by the Bureau within the limits of tolerance stated thereon. The cavities must be concentric with the exteriors and of ample capacity to insure a satisfactory fragmentation when the shell is burst with black powder.

(3) They must be made of the best quality of steel, and must be sound and free from cracks, blowholes, and all other defects seriously affecting their resistance and value as projectiles; this condition to be determined by the Government inspectors.

(4) At the specified distance from the base a groove or band-score, well undercut and carefully roughened in the manner prescribed on the drawings, must be turned for the rotation-band. The rotation-band must be of the best quality of pure copper, and must be annealed before banding.

(5) The rough bands may be in the form of strips and hammered or pressed into the score, but solid rings cut from drawn copper tubes will be preferred.

(6) If fitted with base-plugs, a forged-steel base-plug with external thread fitting closely in a corresponding thread cut in the base of the shell, and with an internal thread to take the fuse, is to be set home in each shell, the exterior threads of base-plug and interior threads in the shell being first coated with red-lead. This base-plug must fit gas-tight. The Bureau reserves the right to have the shape or dimensions of the base-plug changed at any time, which shall be done without extra charge.

(7) Shell of 8-inch, 10-inch, 12-inch, and 13-inch calibers must have an annular groove turned in the face of the base, to be of the dimensions prescribed by the Bureau for fitting base-covers.

(8) All shell must be capped with caps of soft steel furnished by the contractor, fitting over the head and being secured in place by proper methods approved by the Bureau.

(9) All shell must be thoroughly cleaned, the cavities carefully coated with a suitable lacquer.

(10) Chemical and physical tests may be made for the purpose of insuring uniformity in each lot, and the requirements shall be as follows:

(a) A specimen from each forging or casting shall be analyzed for carbon, chromium, or other hardening element, and as shown thereby, the carbon percentage of no shell in any lot shall vary more than ten one-hundredths of 1 per-cent from the mean carbon percentage of the entire lot, and the chromium percentage or percentage of other hardening element in no shell in any lot shall be less than that fixed by the contractor as a minimum percentage suitable for the class of shell constituting the lot.

(b) Transverse specimens may be taken from the base of three shell of each lot after annealing, and, as judged by their test, all the shell of each lot shall be of substantially uniform quality of metal.

Caliber of shell	Thickness of plate *Inches*	Striking velocity	
		Harvey *Foot-secs.*	Krupp *Foot-secs.*
3 inches (14-pounder)	3	2,025	.....
	4	2,550	.....
	4.5	2,800	.....
4 inches	4	1,925	.....
5 inches—50 pounds	5	2,075	.....
	6	2,400	.....
	7	2,700	.....
5 inches—60 pounds	5	1,900	.....
	6	2,200	.....
	7	2,500	.....
	7.5	2,625	.....
6 inches	6	1,870	1,990
	7	2,100	.....
	8	2,321	.....
	9	2,553	.....
7 inches	7	1,795	1,975
	8	1,995	.....
	9	2,170	.....
	10	2,360	.....
8 inches	8	1,730	1,930
	9	1,890	.....
	10	2,050	.....
	11	2,200	.....
	12	2,350	.....
10 inches	10	1,625	1,900
	11	1,750	.....
	12	1,875	.....
	13	2,000	.....
	14	2,125	.....
	15	2,250	.....
12 inches	12	1,600	1,880
	13	1,700	.....
	14	1,800	.....
	15	1,900	.....
	16	2,000	.....
	17	2,100	.....
13 inches	13	1,550	1,850
	14	1,650	.....
	15	1,750	.....
	16	1,850	.....
	17	1,950	.....

For intermediate thicknesses the velocity shall be determined by interpolation.

(11) After final treatment and before submission to ballistic test, each shell shall be subjected to an internal hydraulic pressure of 500 pounds to the square inch, and any shell which develops unsoundness, holes, or cracks, or leaks around base-plug will be rejected.

(12) The shell shall be presented for acceptance completely finished, except banding, lacquering, and capping, in lots of 500 3-inch, 400 4-inch, 400 5-inch, 350 6-inch, 350 7-inch, 350 8-inch, 300 10-inch, 300 12-inch, and 300 13-inch.

(13) Four shell shall be selected from each lot and shall be banded and capped. Of these one will be fired over the range to observe the character of its flight, or if the Bureau so elects this or another shell may be burst in the explosion chamber for fragmentation.

(14) The three ballistic shell shall be fired against a face-hardened plate from 1 to 1½ calibers thick, with a striking velocity given by the foregoing table. Two of the shell shall go through the plate unbroken and be then in a condition for effective bursting.

(15) If any lot fails on any test three shell may be again selected for the same test with the requirement that all must pass the test. On the second failure the lot shall be rejected. If necessary, the inspector may cause finally rejected shell to be marked or stamped to prevent their being incorporated in other lots. (See Plates I, II, III, and IV.)

Specifications for Target Shell for the United States Navy.

15. (1) **Target shell** will be manufactured in accordance with the exterior dimensions shown on the Bureau's drawings of armor-piercing shell.

(2) The shell must be of domestic manufacture and must be finished to the dimensions shown on the drawings approved by the Bureau within the limits of tolerance stated thereon. The cavities must be concentric with the exteriors.

(3) They must be made of a good quality of cast or forged-steel, and must be sound and free from cracks, blowholes, and all other defects seriously affecting their resistance and value as projectiles; this condition to be determined by the Government inspectors.

(4) At the specified distance from the base a groove or band-score, well undercut and carefully roughened in the manner prescribed on the drawings, must be turned for the rotation-band. The rotation-band must be of the best quality of pure copper, and must be annealed before banding.

(5) The rough bands may be in the form of strips and hammered or pressed into the score, but solid rings cut from drawn copper tubes will be preferred.

(6) If fitted with base-plugs, a steel base-plug with external thread fitting closely in a corresponding thread cut in the base of the shell, and with an internal thread to take the fuse, is to be set home in each shell,

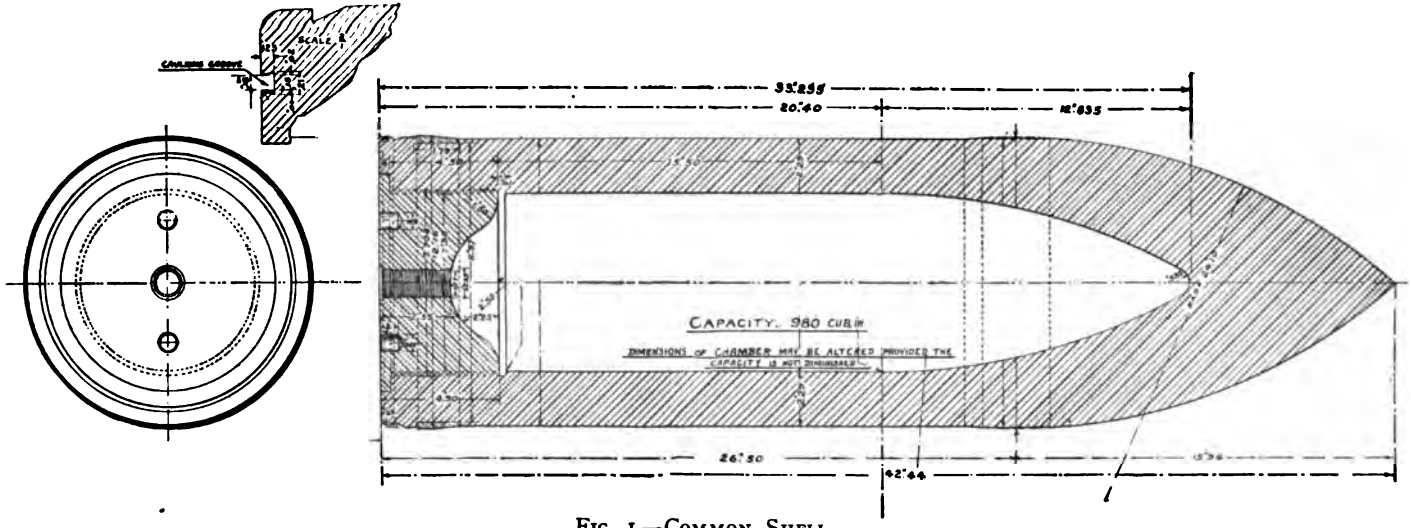


FIG. 1.—COMMON SHELL.

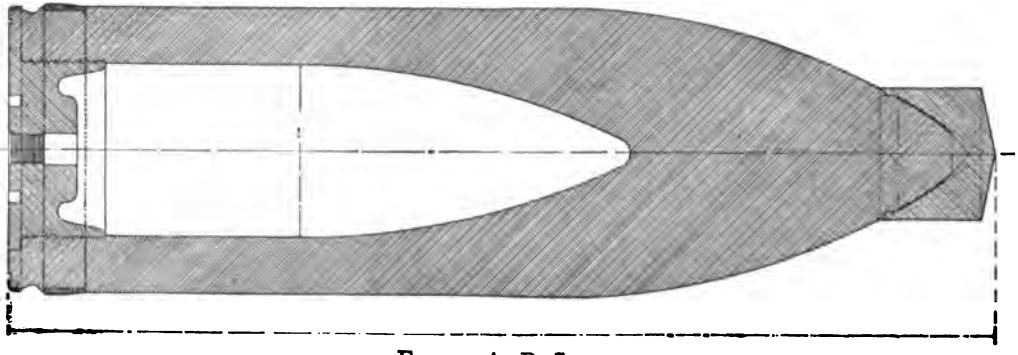


FIG. 2.—A. P. SHELL.
12-INCH PROJECTILES.

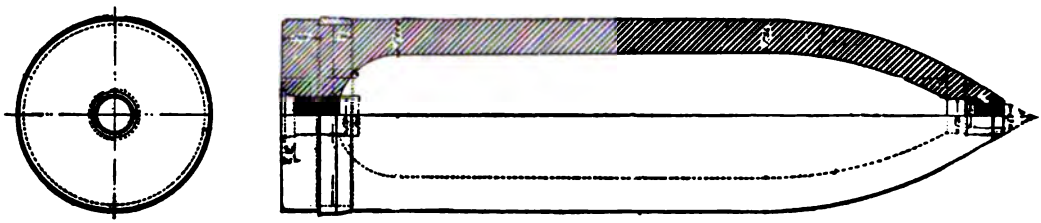


FIG. 1.—COMMON SHELL.

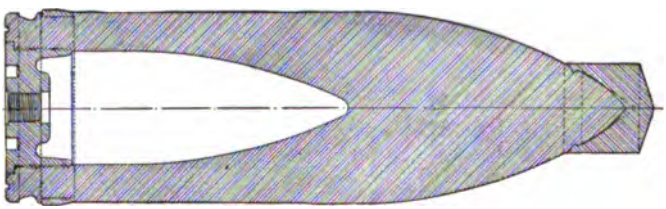


FIG. 2.—A. P. SHELL.

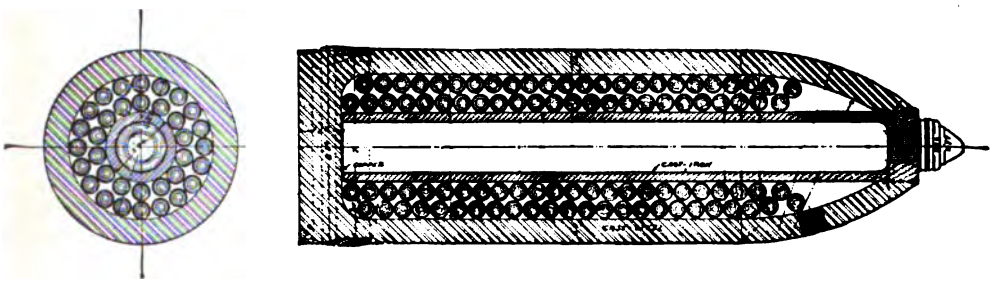
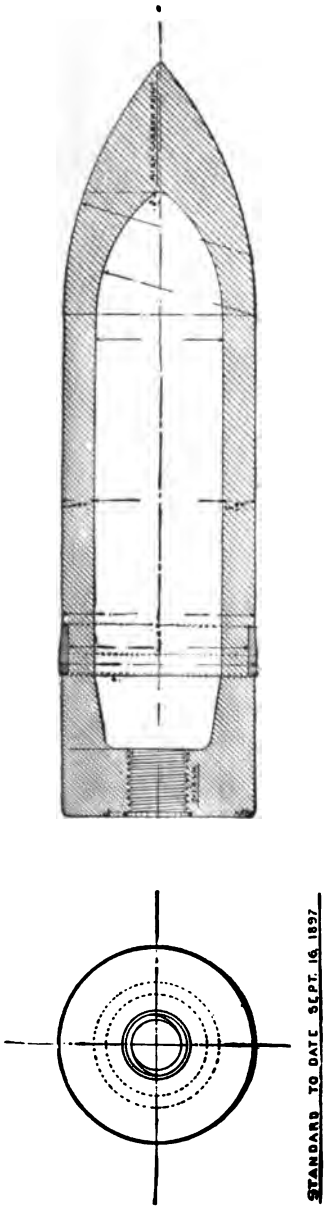


FIG. 3.—SHRAPNEL.

8-INCH PROJECTILES.



STANDARD TO DATE SEPT. 16, 1897

FIG. 1.
COMMON SHELL.

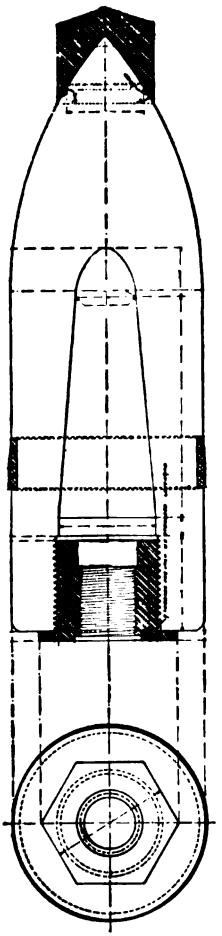
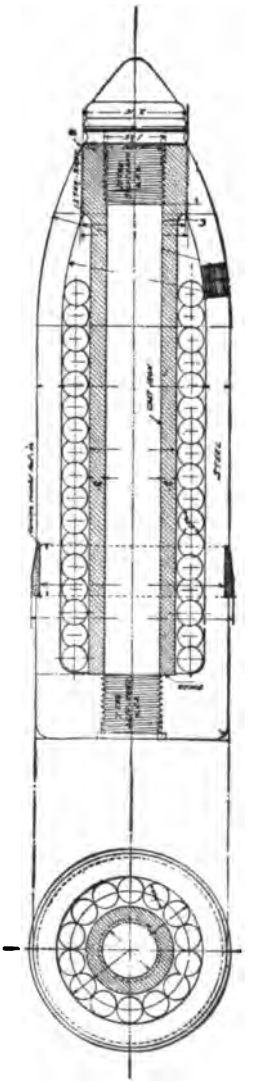


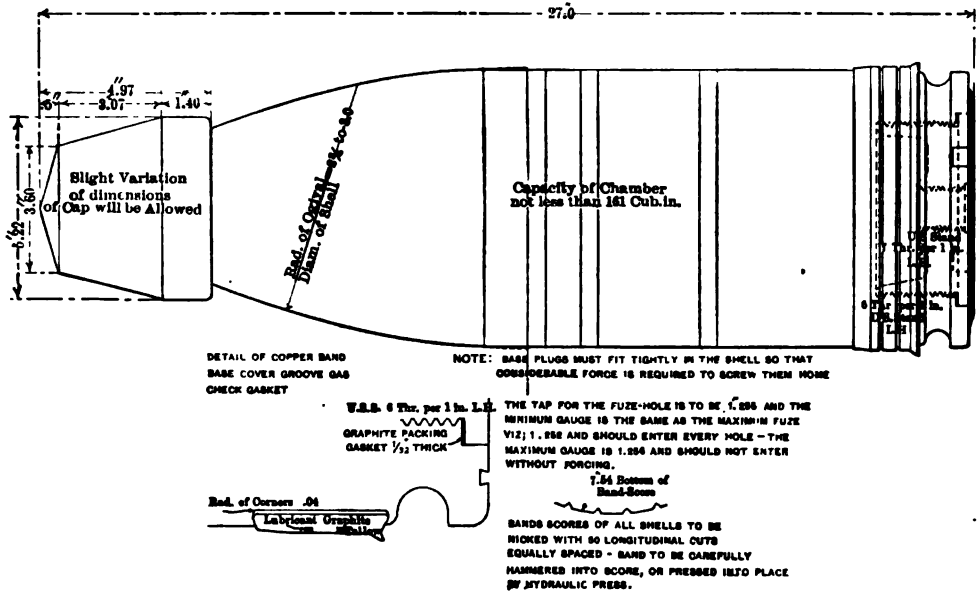
FIG. 2.
A. P. SHELL.



NOTE. The Shrapnel Body may be made with Base Solid or with a Base-Plug.

FIG. 3.
SHRAPNEL.

4-INCH PROJECTILES.


27.0
2.97
3.07
1.40
3.50
6.72
Slight Variation of dimensions of Cap will be Allowed
Rad. of Ogive
Diam. of Shell = 2.5 to 3.0
Capacity of Chamber not less than 161 Cub.in.
DETAIL OF COPPER BAND
BASE COVER GROOVE GAS
CHECK GASKET
W.S.S. 6 Thr. per 1 in. L.H.
GRAPHITE PACKING
GASKET 1/32 THICK
Rad. of Ogives .04
Lubricant Graphite
NOTE: BASE PLUGS MUST FIT TIGHTLY IN THE SHELL SO THAT CONSIDERABLE FORCE IS REQUIRED TO SCREW THEM HOME
THE TAP FOR THE FUZE-HOLE IS TO BE 1.256 AND THE MINIMUM GAUGE IS THE SAME AS THE MAXIMUM FUZE VIZ; 1.256 AND SHOULD ENTER EVERY HOLE — THE MAXIMUM GAUGE IS 1.256 AND SHOULD NOT ENTER WITHOUT FORCING.
7.54 Bottom of Band-Score
BANDS SCORED OF ALL SHELLS TO BE NICKED WITH 90 LONGITUDINAL CUTS EQUALLY SPACED - BAND TO BE CAREFULLY HAMMERED INTO SCORE, OR PRESSED INTO PLACE BY HYDRAULIC PRESS.

OUTLINE OF NEW A. P. SHELL, SHOWING NEW DRIVING-BAND AND DETAILS OF BASE-COVER. TARGET SHELL MUST CONFORM TO THIS PLAN. (CAVITY NOT SHOWN).

the exterior threads of base-plug and interior threads in the shell being first coated with red-lead. This base-plug must fit gas-tight.

(7) Shell of 8-inch, 10-inch, 12-inch, and 13-inch calibers must have an annular groove turned in the face of the base, to be of the dimensions prescribed by the Bureau for fitting base-covers.

(8) All shell must be capped with caps of steel furnished by the contractor, secured in place by proper methods approved by the Bureau. The cap may be cast, or forged solid, with the head if this method is preferred by the contractor.

(9) All shell must be thoroughly cleaned, the cavities carefully coated with a suitable lacquer.

(10) Before submission to ballistic test, each shell shall be subjected to an internal hydraulic pressure of 500 pounds to the square inch, and any shell which develops unsoundness, holes, or cracks, or leaks around base-plug will be rejected.

(11) The test for acceptance shall be as follows: Three shell shall be selected from each lot; shall be banded and capped, and shall be fired over the range. All shell must give a smooth flight and none must upset, break up, or strip the band in flight.

(12) If any lot fails on the first test the lot may be submitted a second time, three shell being again selected with the requirement that all must pass the test, but, on a second failure, the lot shall be rejected. If necessary, the inspector may cause finally rejected shell to be marked or stamped to prevent their being incorporated in other lots.

Specifications for Shrapnel.

16. (1) **The body of the shrapnel** must be of cast-steel or drawn-steel and the powder tube of cast-iron, and must be finished to the dimensions shown on drawings approved by the Bureau of Ordnance and within the limit of tolerances stated thereon.

(2) Where no tolerances are mentioned they must be as near to standard dimensions as careful machining will make them, or as the requirements of the parts warrant. This to be determined by the Bureau of Ordnance or its representative.

(3) The fuse-holes must be tapped, unless otherwise arranged, and the shrapnel banded with bands of pure annealed copper.

(4) If of cast-steel, the steel used must be of the same quality and grade as that used for cast-steel shell.

(5) The castings for the powder tubes must be of good quality, free from defects, and as smooth on the interior as the best iron castings, and rejection for such defects shall be final.

(6) The bullets must be uniform in size within tolerances determined by the inspector, and none are to exceed in diameter the dimensions shown on the prints.

(7) The shrapnel of each caliber are to be presented for acceptance in lots of 500.

(8) One per-cent of each lot presented, to be selected by the inspector, to be tested as follows for acceptance of the lot:

(9) When practicable, a lot of fuses shall be tested for acceptance with each lot of shrapnel, and in that case one or more of the shrapnel, loaded and fused and with the fuse set for percussion-firing, shall be dropped in an explosion chamber, the fuse-wire having first been cut, to observe the character and completeness of burst, and the remainder of the test shrapnel shall be fired over a range with service charges to observe the time-action of the fuses.

(10) When fuses are not tested in conjunction with the shrapnel, the acceptance tests of the latter will consist of bursting one or more of the selected shrapnel in an explosion chamber, by any suitable means, and firing the remainder, blind loaded, with service charges, over a range. Those burst in the explosion chamber must break up well, and those fired over the range must not break or set up in the gun; their flight must be smooth, and their rotating-bands must not come off in flight.

(11) **The powder chambers** of the shrapnel must be suitably lacquered, and the balls must be bedded in a suitable matrix, approved by the Bureau.

Preparation of Shell for Service.

17. The following is a summary of the instructions of the Bureau of Ordnance regarding the preparation of armor-piercing and common shell for issue to service:

(1) Only blind shell will be assembled in 1-pounder ammunition for use in sub-caliber practice. These shell are to be brought to standard weight by filling with sand, and the fuse-holes plugged with metal plugs, each marked "plug."

(2) All loaded shell except for 1-pounder, 3-pounder, and 6-pounder calibers will be loaded with burster-bags.

(3) All armor-piercing shell will be loaded with fine black powder and fused, except that armor-piercing shell above 6-inch caliber will not be loaded unless fitted with base cup-gas-checks. Unloaded armor-piercing shell issued to service will have the fuse-holes plugged with metal plugs, each marked "plug."

(4) All common shell (cast-iron, cast-steel, and forged-steel), above 6-inch caliber, fitted with base-plugs or base-fuses, are to be fitted with base gas-check covers. Common shell of and below 6-inch caliber will not be so fitted. Cast-iron shell when so fitted may be issued as common shell.

(5) In loading shell having base-plugs, great care is to be observed to see that the base-plug, after having been given a thin coat of red-lead and oil, is set home tight, and that the fuse is set home tight, after being luted with small-arm shellac.

General Remarks on Shells.

18. The foregoing specifications and instructions of the Bureau of Ordnance contain nearly all the necessary information regarding service projectiles. Additional information regarding the development of modern projectiles, the action of the steel cap, ballistics, etc., will be found in the chapters on "Armor" and "Penetration of Projectiles," by Lieutenant Cleland Davis, U. S. Navy, and the details are shown in Plates I, II, III, IV, V, VI, and VII.

19. Radius of the ogival.—The radius of the ogival in service shells is not fixed, but varies from 2 to 3 calibers. The latest armor-piercing shell have an ogival head of 2¾ calibers. In nearly all other shell the radius is 2 calibers.

20. Base-plugs.—Nearly all shell are fitted with base-plugs, but some are cast or forged with solid bases, as shown in the plates.

21. Fuses.—As a rule, base-fuses only are used, except for shrapnel, which are fitted with combination, time, and percussion nose-fuses. There are, however, some old common shell in service, fitted with nose-fuses, as shown in Plate II.

22. Base-covers.—Nearly all shell of large caliber (6-inch and above) are fitted with base-covers (see Plate V, Fig. 3). The holes for the spanner in the base of the plug are first filled with lead, and a lead disk is then placed over the base of the shell, covering the plug and fuse. A copper disk is then placed over the lead and caulked into the base of the shell, the caulking-groove being filled with a lead wire, as shown in the plate.

23. The function of the base-cover is to prevent the penetration past the thread of the fuse or base-plug, to the interior of the shell, of the gases formed by the explosion of the powder charge, which, in the case of a projectile containing a bursting-charge, might explode the shell, or, in a blind-loaded projectile, disrupt it.

24. Steel cap for armor-piercing shell.—In order to assist the shell in its attack on hard-faced armor, and to assist in biting into an armor-plate, all armor-piercing shell are now fitted with a soft steel cap of the shape shown in Plates IV and V. The steel cap protects the sharp point of the shell and supports the head on its first impact with face-hardened armor. The method of attaching the soft steel cap is shown in Plate V. The cap, *C*, Fig. 1, Plate V, is placed in a hardened steel die, *D*, the projectile is then placed on it vertically as shown, and under the hydraulic pressure of a 25-ton ram, *H*, is forced downward until the die is about to touch the projectile. No machine work is necessary, the surplus metal on the exterior of the cap being just sufficient to fill the score in the projectile.

25. Driving or rotating-band for projectiles.—The rotating-band for all shell and shrapnel is of copper, shaped as shown in the plates, and is forced into an undercut score on the surface of the projectile, near the base, by hydraulic pressure, after which it is machined to size. The standard band is a few hundredths of an inch larger in diameter than the caliber of the gun, the soft metal being forced to flow into the grooves of the rifling when the projectile is fired. It is important that the band should not slip, since it is the velocity of rotation that keeps the shell steady in flight and prevents tumbling.

26. The new driving-band shown on Plate IV will probably be made the standard for all projectiles not contained in a cartridge-case. It is believed to cause less wear in the rifling of the gun than the solid band, by providing for a flow of the metal into its grooves, and by furnishing lubrication.

27. Remarks on armor-piercing shells.—Plate IV shows the exterior form of the new armor-piercing shell. This shell, containing a large bursting-charge, is required to penetrate its own thickness of face-hardened armor, and to then be in a condition for effective bursting, thus combining to a considerable degree the attributes of armor-piercing and common shell.

28. This shell may be called the "battle shell." Blind-loaded target shell, similar to it in all respects, except as to material, will be supplied for practice.

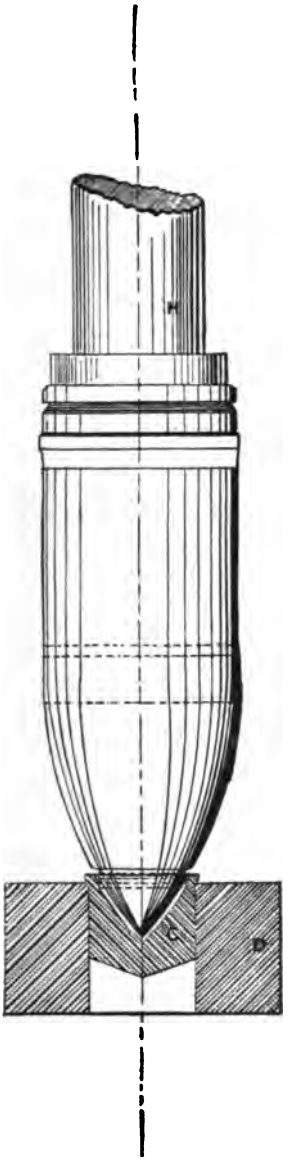


FIG. 1.
METHOD OF CAPPING ARMOR PIERCING SHELL.

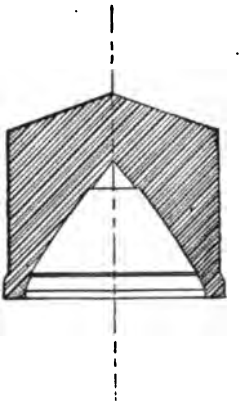


FIG. 2. STEEL CAP.

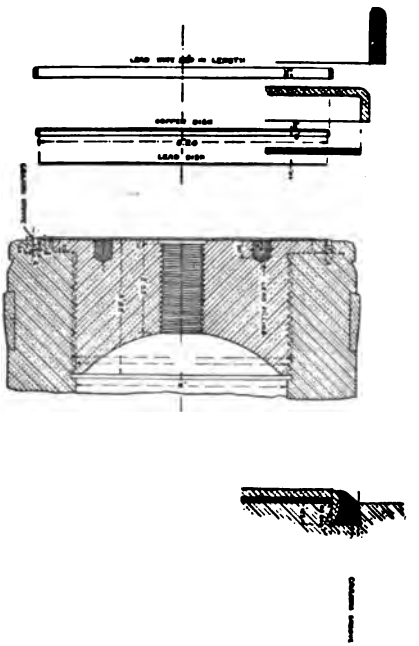


FIG. 3.
BASE COVER FOR SHELLS.

FIG. 1.

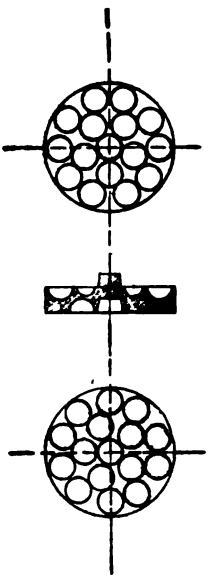


FIG. 2.

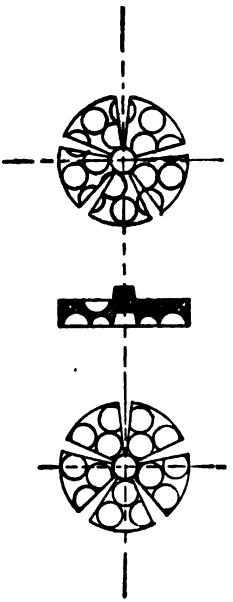


FIG. 3.

3-INCH SHRAPNEL R. F. FIELD-GUN.

29. Remarks on common shell.—Common shell have been made of cast-iron, cast-steel, and forged-steel. The forged-steel shell, being tough and having good penetrating power, has sometimes been called "the semi-armor-piercing shell." The term *common shell* is preferred, however. Plates I, II, and III show the details of three sizes of common shells.

30. Bursting-charges for common shell.—The following are the approximate weights of the bursting-charges, of small-grained black powder, for common shells:

Gun	Weight of shell	Weight of bursting-charge
1-pdr. and 37 mm. R. C.	1 lb.	270 grains
47 mm. R. C.	3 lbs.	600 grains
3-pdr.	3 lbs.	900 grains
6-pdr.	6 lbs.	1450 grains
4-in.	33 lbs.	2 lbs.
5-in.	50 lbs.	3 lbs.
6-in.	100 lbs.	3¼ lbs.
8-in.	250 lbs.	10 lbs.
10-in.	500 lbs.	20 lbs.
12 in. cast-steel	850 lbs.	60 lbs.
12-in. forged-steel	850 lbs.	36 lbs.
13-in. forged-steel	1100 lbs.	50 lbs.

31. High explosive shells have not been issued to service, but the subject is under consideration and is touched upon in the chapter on "Penetration of Projectiles."

32. It has been proposed to place smoke-producing materials of different colors in the different calibers of shells so that the bursting of the shells would indicate, by the color of the smoke, where each caliber falls. This plan might be of use in bombardments to discover the correct range and to show what shell strike over or short.

Shrapnel.

33. (1) Both cast-iron and steel shrapnel have been issued for guns from 3-inch to 8-inch in caliber, but in future steel shrapnel only will be issued.

(2) Plates II, III, VI, and VII show the details of shrapnel of three different calibers. It will be seen that the body of the shrapnel is made of steel of comparatively thin walls, and that the details are different for the several calibers. Sometimes the burst-

ing-charge is in the point, sometimes in the base, and again in the central tube.

(3) The number of balls varies with the caliber; in the 4-inch shrapnel it is about 270, and in the 5-inch about 360, of .52-inch diameter. The 6-inch shrapnel has about 210 balls of .82 of an inch diameter.

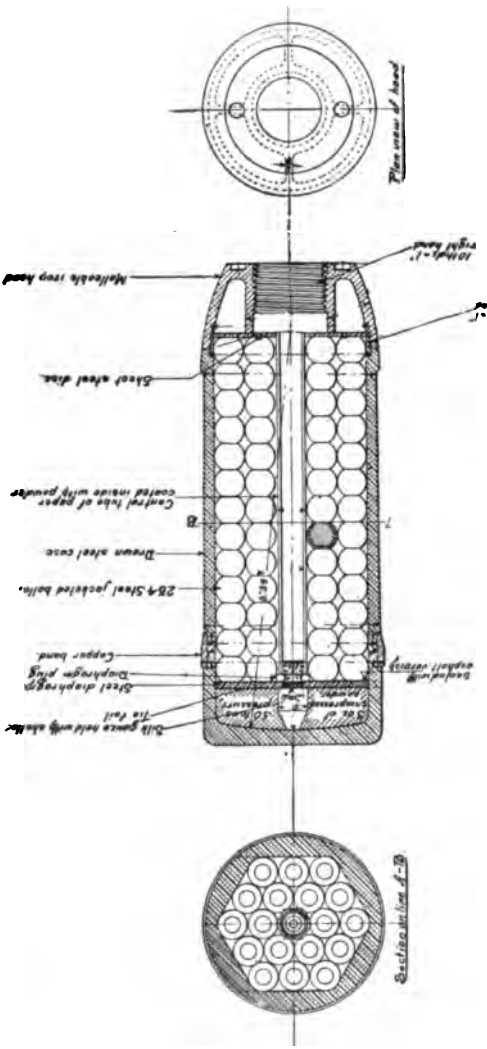
34. Fuse for shrapnel.—Combination time- and percussion-fuses for shrapnel are described in Chapter XXIX.

35. Shrapnel for 3-inch field gun.—The following is a description of the shrapnel for the 3-inch field gun:

It consists of a thin cylindrical body about two-tenths inch in thickness, with a cast-iron head, containing the cavity for the bursting-charge, a threaded hole for the fuse, and a base-plug, also of cast-iron. (See Plate VI.) Within the body of the shrapnel are packed 135 balls, ½ inch in diameter, which are held in place by two cast-iron supporting disks, Fig. 2, Plate VI, and by six cast-iron separator-disks, Fig. 3, Plate VI. The separator-disks are cut radially into five sectors. The fuse screws into the fuse-hole in the cast-iron head.

36. New 3-inch shrapnel.—The latest 3-inch shrapnel is shown in Plate VII.

37. The bursting-charges of shrapnel.—The bursting-charges, as compared to shell of the same caliber, are very small, a few ounces only, the amount being just sufficient in each case to crack the walls of the shrapnel, allowing the balls and fragments to be carried forward by the remaining velocity at the instant of bursting, the cone of dispersion being due to the small bursting-charge and the impinging of the balls on each other. The charges are as follows: 4-inch, ⅓ pound; 5-inch, ½ pound; 6-inch, ¾ pound, approximately.



LATEST 3-INCH SHRAPNEL.

CHAPTER XXIX.

FUSES.

PREPARED BY ENSIGN HAROLD E. COOK, U. S. NAVY.

General Remarks.

1. Definition.—A fuse is a specially constructed device which, when exploded by the action of its mechanism, ignites the bursting-charge in a projectile.

2. The fuses which are now in use in the naval service are of two types:

(1) *Base-percussion fuses,* which explode upon impact of the projectile.

(2) *Point-combination fuses,* which may be set to explode either on impact or at a certain instant of their flight.

3. Delayed-action fuses, which are used with armor-piercing shell using high explosives, are not used in the navy.

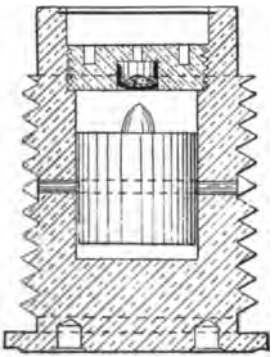
4. (1) **The stocks of all base-fuses** are of brass or bronze and have a left-handed screw-thread to prevent their being unscrewed by the rotation of the projectile in flight.

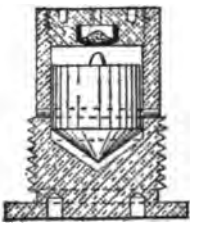
(2) Fuses for projectiles of caliber smaller than 4-inch are called *minor caliber.*

(3) Base-fuses screw into a recess in the base of projectiles and have flanged bases. Base-fuses are used in common and armor-piercing shell, and point-fuses are used with shrapnel.

(4) Fuse-hole plugs of solid brass or bronze are used to screw into the base of blind shell.

(5) All new fuses and plugs are to be made of bronze of high tensile strength. This prevents their being blown out and insures the shell bursting.





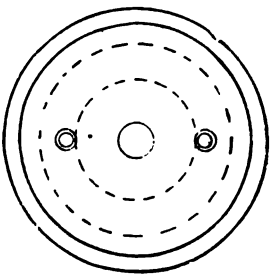


FIG. 1.

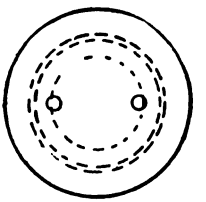


FIG. 2.

NAVY BASE-PERCUSSION FUSES.
Old Type.

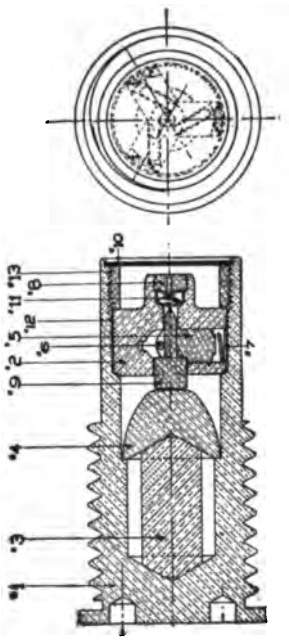


FIG. 1.
MERRIAM FUSE.

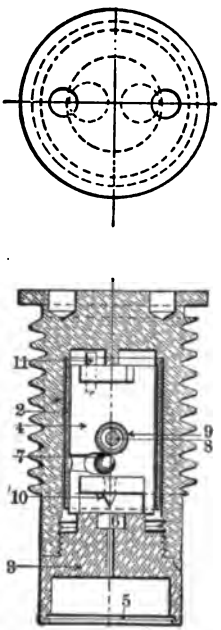


FIG. 2.
WILSON-LYNCH FUSE.

Service-Fuses.

5. (1) The base-percussion fuses now being manufactured for the service are the Watson, Wilson-Lynch, Wilson-Chase, and Merriam for major-caliber shell; the Semple and Wilson-Chase for minor-caliber. (See Plate IX.)

(2) *For shrapnel* there are being manufactured the Frankford Arsenal 21-sec. and the Bethlehem 12-sec. point-combination fuses.

(3) There are in service a large number of the navy base-fuses and the Sweet and Frankford Arsenal 15-sec. point-combination fuses; also some minor-caliber fuses of various types, all of which have been discarded and are being used up.

6. Base-percussion fuses.—Plates I to IX inclusive show all the base-percussion fuses now being made for the service, also the old navy base-fuses. All the new fuses except the Semple are armed by the action of centrifugal force.

7. (1) **The navy base-percussion fuses** are shown in Plates I and IX. The action of these fuses is as follows: The shock of firing causes the inertia of the plunger to break the wire holding the plunger, and on impact the plunger flies forward and explodes the primer-cap.

(2) As a rule these fuses will explode on passing through ¼-inch steel plates. With these old base-fuses a drop of 30 feet upon well-supported half-inch steel plate does not arm them, but a drop of about 12 feet upon a heavy armor plate will do so, hence every precaution should be taken in handling them. They were discarded in favor of the new centrifugal fuses, as it was found to be difficult to find the proper thickness for the shear-wire.

8. Merriam base-percussion fuse.—(1) The Merriam base-percussion fuse, of which a number have been ordered for issue to the service, is shown in Plate II, Fig. 1, and in Plate IX.

(2) The *striker* (9), the *primer* (11), and *anvil* (8) are carried in a block (2) held in the forward part of the fuse cavity by a screw-sleeve (13). The flame from the primer communicates with a small powder-chamber, the powder being confined by a thin copper disk (10).

(3) The point of the striker is held back from the primer in the block by three radial keys (5) which are pressed against the

striker by spiral springs, as shown in the plate. When the shell leaves the gun the centrifugal force due to the rotation of the shell causes the keys to fly back against the springs and unlock the striker, which is then free to move forward against the primer.

(4) The plunger, which gives force to the striker, is in two distinct parts (3 and 4). The rear plunger (3) is designed to cause the fuse to act upon oblique- or side-impact. Being of smaller diameter than the fuse-cavity and its ends being conical where it bears against the cavity and against the forward plunger (4), it is evident that a side-impact would cause the plunger to move sidewise and impart a forward movement to the forward plunger (4), driving the latter against the striker (9).

(5) The action upon direct impact will be evident from the plate. The centrifugal locking- or safety-arrangement and the device for side-impact are the distinguishing features of this fuse.

(6) This fuse, though satisfactory in its action, is so complicated and expensive that its manufacture will probably be discontinued after the present order is filled.

9. Wilson-Lynch base-percussion fuse.—This fuse, which is being manufactured at the Naval Gun Factory, is shown in Plate II, Fig. 2, and in Plate IX. It consists of the following parts: the stock (1), sleeve (2), magazine (3), plunger (4) [plunger consists of two parts, male (*a*) and female (*b*), held together by the spring-screw (8) and spring (9)], annealed copper disc (5), primer-cap (6) which is a Winchester No. 2 of copper, steel ball (7), firing-point (10), and starting-pins (11). The powder-chamber in the magazine (3) is filled with 60 grains of black powder, the copper disc is expanded into place and sealed with shellac. When the plunger is closed a small shoulder on the magazine holds the plunger central, the point is then out of line with the cap. The action of this fuse is as follows: When the gun is fired and the shell starts its rotation the plunger tends to lag behind, but the starting-pins (11) bring up in the recesses in the base of the stock cavity and start the opening of the plunger. The sleeve (2) prevents the plunger sticking to the wall of the fuse, as the commencement of the rotation would tend to throw the plunger violently to the side. As soon as the projectile obtains a rotation of about 3000 revolutions a minute the plunger opens out and the steel ball which

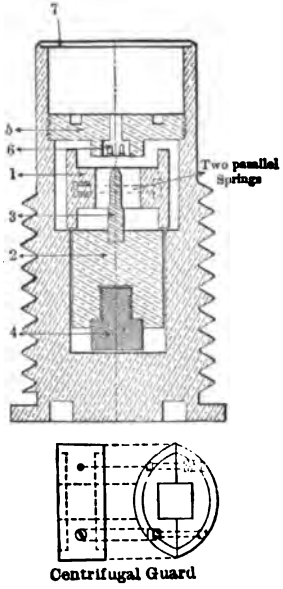


FIG. 1.

WILSON-CHASE FUSE.

Major-Caliber.

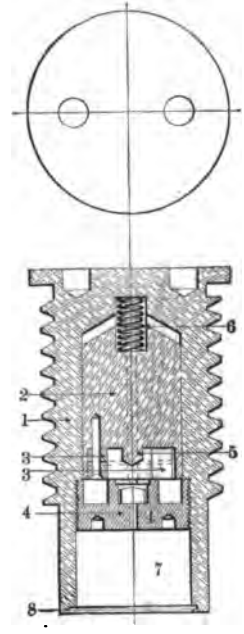


FIG. 2.

WATSON FUSE.

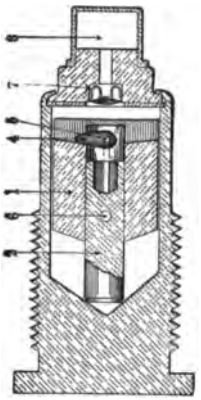
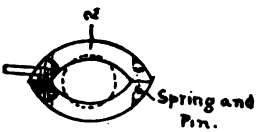


FIG. 1.

SEMPLE FUSE.
Minor Caliber.



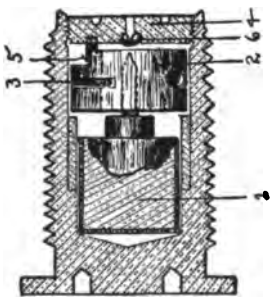


FIG. 2.

WILSON-CHASE FUSE.
Minor Caliber.

has rested in the recess in the plunger now flies out, along the groove of decreasing depth, and holds the plunger open. Upon impact the plunger flies forward, and the point, now being in a central position, strikes the primer-cap, exploding it. The design of this fuse as submitted by the U. S. Ordnance Co., the owners of the patents, provided for side-impact weights behind the plunger, but the side-impact explosion not being considered necessary, this feature is omitted in the fuses being made for the service. The fuse shown in Plates II and IX is improvised so as to use up a number of old Frankford Arsenal ring-resistance fuse-stocks. The standard fuse has a stock and closing plug similar to the Wilson-Chase, and a heavier plunger.

10. Wilson-Chase base-percussion fuse (major-caliber).—This fuse, which is being manufactured for the service by the U. S. Ordnance Co., who own the patents, is shown in Plate III, Fig. 1, and in Plate IX. It consists of the following parts: the stock, the centrifugal-guard (1), plunger (2), point (3), lead-base (4), closing-plug (5), primer-cap (6) [Winchester No. 2½, brass], copper disc (7). The plunger is held to the rear by the centrifugal guard (1), which is in two parts held together by two springs and screws, which are parallel (shown in the section). The lead-base (4) is to prevent the plunger being driven forward by any heavy blow on the base of the fuse. The action on being fired is as follows: When the projectile is in flight the guard opens out, due to the high rotation, and the plunger, which has been held to the rear by the guard-ring, can now fly forward sufficiently to drive the point into the primer-cap on impact.

11. The Watson base-percussion fuse.—This fuse, which is being made for the service by the Watson Ordnance Company, of Pittsburg, is shown in Plate III, Fig. 2. It consists of the following parts: the stock (1), plunger (2), pawls, springs and hinge-pin (3), primer-plug (4), point (5), which is of bronze and is part of the plunger, plunger-spring (6), and copper disc (8), There are two longitudinal slots in the plunger diametrically opposite and a starting-pin in the stock travels in one of them. The parts are made of bronze of about 50,000 pounds tensile strength. The action of the fuse is as follows: The shock of discharge causes the plunger to set back against the spring (6) at its rear, which

releases the lugs of the safety-jaws (3) from engagement with the inner side of the primer-hub, which engagement had locked the plunger in the safety position. The acceleration of the shell through the bore of the gun and for a short distance beyond holds the plunger to the rear. This action is aided by the rotation-pin, which engages the longitudinal slot in the side of the plunger which gives to it a positive rotation and is in turn imparted to the jaws (3), the whole being actuated by the projectile. This rotation by centrifugal action throws the jaws to the periphery of the plunger and once the shell is in flight the spring at the rear forces the plunger forward until the jaws are on the outside of the primer-hub, when they are locked open to allow the plunger to move forward and explode the primer-cap, a brass Winchester No. 2½, on impact. The fuse is therefore locked in both safety and armed positions. The sectioned fuse in Plate IX is shown in the armed position.

12. Semple base-percussion fuse (minor-caliber).—This fuse, which is being manufactured for the service, is shown in Plate IV, Fig. 1, and in Plate IX. It consists of the following parts: outer plunger (1), inner plunger (2), magazine (3), knife (4), knife-pin (5), shear-wire (6), and primer-cap (7). In the safety position as shown the outer plunger rides forward on the inner plunger and is held there by a copper shear-wire. The knife (4) is carried in a slot in the outer plunger and in the safety position is folded inside. The front part of the fuse is shaped to form the magazine (3) and holds a small charge of powder and the primer-cap. The action of the fuse is as follows: The shock of firing shears the wire and the outer plunger flies back, due to inertia, sliding over the inner plunger. The slot in the inner plunger forces out the knife and upon impact both plungers fly forward and explode the cap. The fuses, as are all minor-caliber fuses, are now made long-threaded.

13. Wilson-Chase minor-caliber fuse.—This fuse, which is shown in Plate IV, Fig. 2, and in Plate IX, is similar to the major-caliber fuse and consists of the following parts: Plunger (1), centrifugal-guard (2), retaining-pin (3), primer-plug (4), starting-pin (5), and primer-cap (6). There is no magazine. The plunger is encased in lead. The centrifugal-guard opens out on a hinge and spring and a small retaining-lever flies out and holds

FIG. 1.

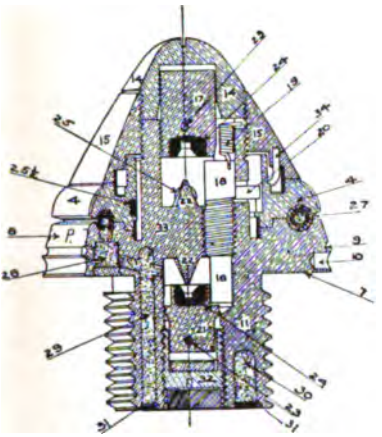
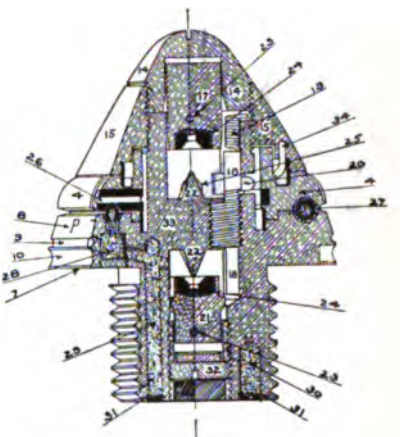


FIG. 2.



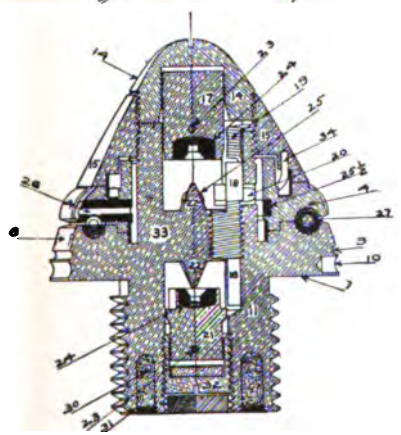


FIG. 3

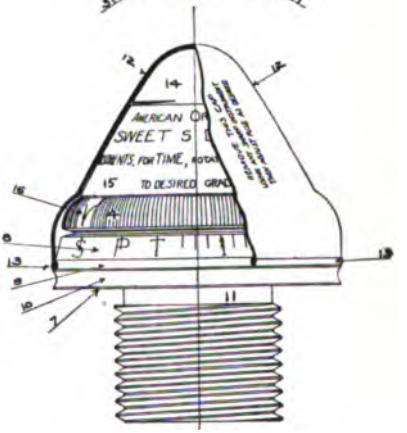
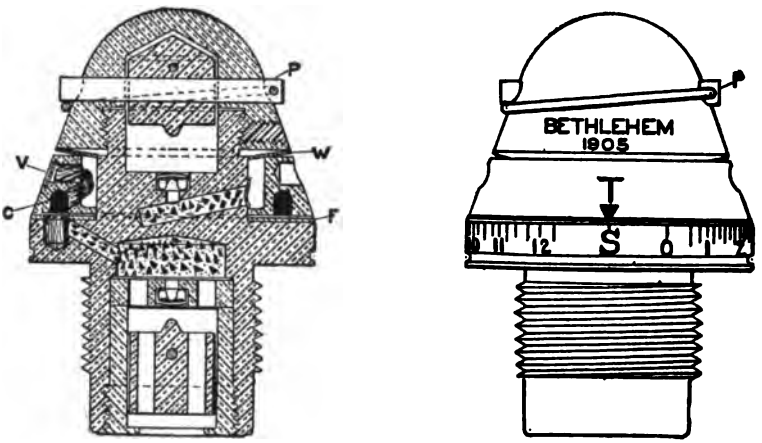


FIG. 4.

SWEET'S FUSE.



BETHLEHEM FUSE.

it armed. The starting or rotating-pin in the plug engages in a slot between the two parts of the guard and insures prompt arming. In the latest fuses the retaining-lever is omitted. The action of this fuse is similar to that of the Wilson-Chase major-caliber.

14. Test and inspection of centrifugal fuses.—The following applies to those manufactured at the gun factory, and the tests of other fuses are similar. Out of every 1000 fuses the inspector carefully gauges about 30. There is a gauge (maximum) in which the fuse must be screwed home, a minimum, which it must just not enter, and a ring-gauge which must fit over the nose. These 30 are then spun in a clutch driven by a motor and each fuse must arm at 3000 revolutions. Two of these fuses are then picked out for drop-testing. The fuse to be drop-tested is screwed in the base of a 4-inch projectile and is dropped from a height of 32 feet, point first, base first, and on its side, on a 4-inch steel plate. The fuse must not arm on any of these drops, and after being drop-tested must be armed at 3000 revolutions on the spinner. Eight fuses that have been spun are picked out and sent to the proving-ground for test, and must explode when fired from a 5-inch, 40-caliber gun at 1000 f. s. m. v., through a 5/8-inch plate at a range of about 300 feet.

Time-Fuses.

15. (1) A *time-fuse* is one which explodes by its own internal action after a definite time of flight, which fixes the *distance* from the gun at which the shell will burst; this interval may be varied within large limits by the operation of "cutting" or "setting" the fuse.

(2) Any time-fuse depends upon its train of compressed slow-burning powder; this composition is made as uniform as possible, and, if accuracy is to be attained, equal lengths of it should be consumed in equal intervals of time. When the fire reaches the end of the time-train, it ignites the quick powder of the fuse-magazine and bursting-charge, and the projectile instantly explodes. The time of burning a particular size or variety of fuse depends upon the distance of the point at which the train is lighted from its end.

(3) The first fuses used for bursting projectiles were time-fuses which depended upon the slow-burning powder train; since that time the only progress, as far as principles are concerned, lies in the method of igniting the time-train. These old-fashioned fuses, formerly used with common shell, were ignited by the flame of the gun's powder-charge which came into contact with the exposed time-train—if it had been "cut." Their bodies were sometimes made of wood, and the time of burning was varied by sawing off a few inches of the end. This method of ignition answered very well, but for modern guns the fuse would have to be in the base of the projectile, and the high powder-pressure would crush one of such construction or at least derange it so as to interfere with its working. The modern method of ignition is self-contained. The methods used vary with the different types, but in general they resemble the methods used in base-percussion fuses.

(4) Time-fuses are used in the navy for shrapnel only, and are invariably carried in the nose of the projectile.

Combination-Fuses for Shrapnel.

16. (1) **Sweet's fuse** (see Plate V) is a combination-fuse, and may be adjusted to act by percussion on striking, or by time. In the latter case, if the time-device fails, the percussion feature will cause an explosion just as if the fuse had not been set for time. The fuse may also be set so that it cannot be exploded by careless handling. Figs. 1 and 2 show the same section but with different settings; Fig. 3 is a section a few degrees from the others, while Fig. 4 is a profile showing the graduations.

(2) *The percussion feature* of the fuse resembles a shear-wire base-fuse; the plunger (21) containing the percussion cap (24) is held by a brittle wire (23); the shock of discharge breaks this and the plunger sets to the rear, arming the fuse; when the projectile strikes, the plunger is carried forward by its momentum, and the cap is exploded by the firing-point (22) which ignites the magazine (29) and produces an immediate burst.

(3) *The time-action* is as follows: The shock of discharge breaks the other shearing-pin (23) and the time-plunger (17)

FRANKFORD ARSENAL 21 SEC. COMBINATION-FUSE

FIG. 1. EXTERIOR.

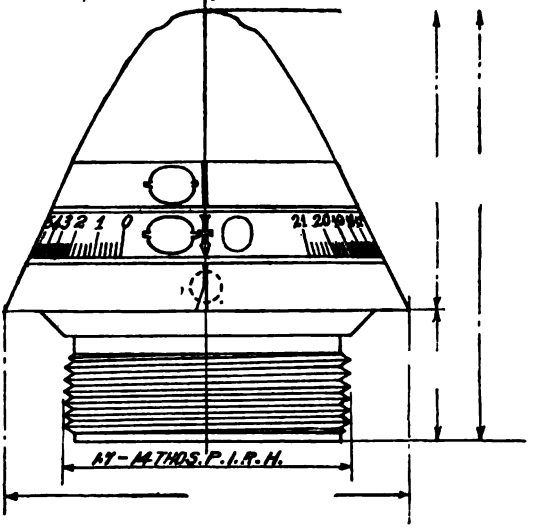


FIG. 2. BEFORE ARMING

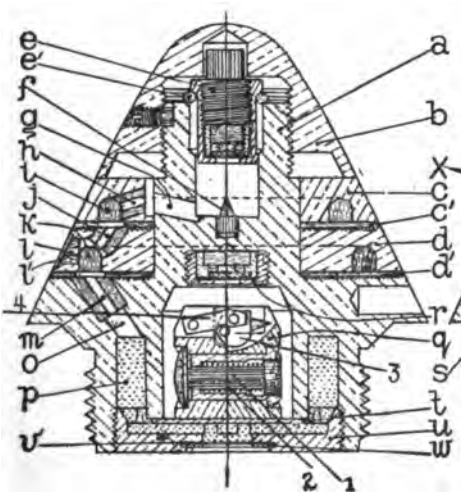
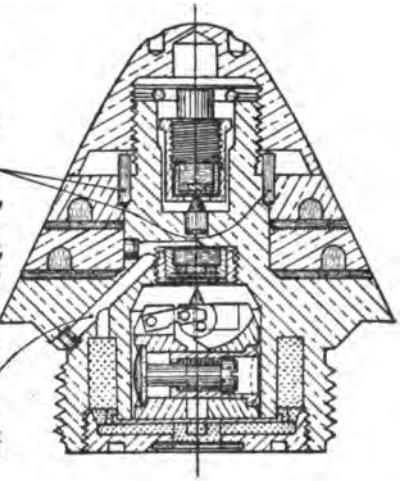
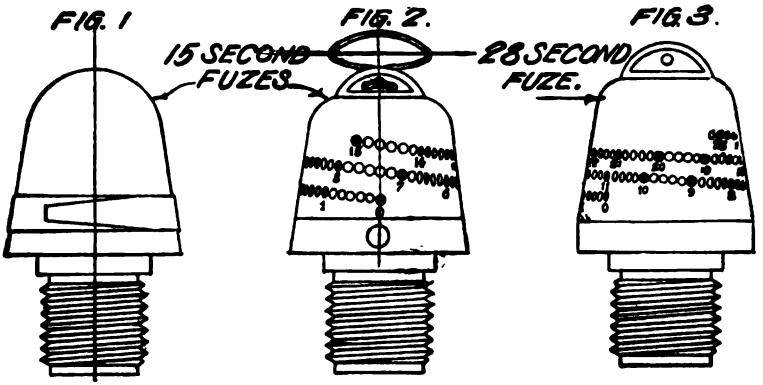


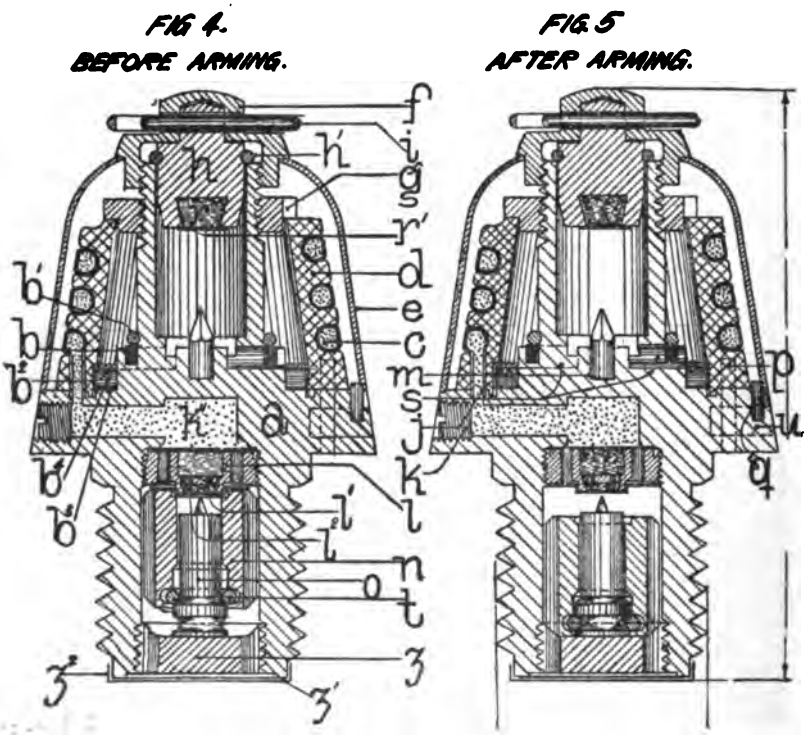
FIG. 3. AFTER ARMING.



FRANKFORD ARSENAL COMBINATION-FUSES. MODEL 1900.



FRANKFORD ARSENAL 15 SEC. COMBINATION-FUSE.



strikes upon the point (22), which explodes the cap (24) and fills the cavity with flame which passes through the hole (25) to an annular space and ignites the ring of powder (25½), and is finally communicated through the hole (26) to the time-train (27) which burns slowly and finally reaches and ignites the powder in (28) and (29). The hole (26) is in the setting-ring (4) and may be moved around with it, thus igniting the time-train at the desired point; this comprises setting it for time.

(4) *The safety-lug* (18), screwed into the body of the fuse, suffices to put the time-plunger out of action, thus setting the fuse for percussion-firing, or to put both plungers out of action, making it insensitive to shock; it is revolved by the action of a stop, on the setting-ring, against the small lug (20). In Figs. 1 and 4 the fuse is set at "safety;" in Fig. 3 for percussion-firing, and in Fig. 2 it would explode, by time, close to the gun.

(5) *The setting-ring* is fitted with pawls which do not permit it to turn in the direction induced by the rotation of the projectile; needless to say, its setting would otherwise be changed. The lead-cap (12) protects the fuse from dampness; it is removed before the fuse is set.

17. Bethlehem-combination time and percussion-fuse.—(1) This fuse is shown in Plate VI. It has plungers and wires similar to those of the usual percussion shear-wire fuse, but the time-plunger is so arranged that the shock of firing not only breaks the wire but explodes the primer-cap, filling the annular cavity of the fuse with flame. This flame escapes through the vent *V*, at the same time igniting the zero end of the time-train, *C*; a piece of quick-match, leading from the time-composition to the vent, insuring ignition. The time-composition, which consists of a special mixture, is loaded in the train disc under considerable pressure. The train is of the horseshoe type and extends through an arc of 315 degrees. The stock is graduated in quarters up to 12 seconds. As the scale is large and distinct, settings of ⅛ second can be made without difficulty. A lock-pin, *P*, which is removed just before setting the fuse, furnishes an additional safety in keeping the time-plunger from impacting against the primer-cap if the ammunition should be accidentally dropped. The spring-washer, *W*, firmly holds the train-disc in set position and insures good

contact of the time-composition with the felt cushion-washer, *F*, so that burning of composition takes place only on radial cross-section of composition.

(2) *The magazine* is filled with fine-grained rifle powder. The percussion element of the fuse is similar to the usual type of wire fuse, except that the plunger is provided with longitudinal flame-passages, as is also the anvil that holds the primer-cap, the holes in the anvil-cap being covered by a thin piece of shellaced linen.

(3) The fuse is made waterproof by dipping it in a bath of shellac, a thin but complete seal being thus formed.

(4) *Setting.*—The lock-pin is to be used as a setting-tool, either end being adapted for insertion in the setting-hole of the train-disc, which should be moved until the index, *T*, is brought in alignment with the graduation of time desired. The initial movement in setting of the disc should be right-handed, as the fuse has a right-handed thread, and reverse motion might have a tendency to unscrew the same from shrapnel head.

18. Frankford Arsenal 21-second combination-fuse.—(1) This fuse which is being made for the naval service, and is the standard for the army, is shown in Plate VII. Most of the parts are made of bronze. There are two time-train rings, *c* and *d*, and an annular horseshoe-shaped groove is milled in the lower face of each ring. Meal powder is compressed into these grooves under a pressure of 70,000 pounds per square inch, forming a time-train, the total length of which is 7 inches.

(2) The time element of this fuse is composed principally of the following parts: the time-plunger *e*, the split-ring spring *e'*, the firing-pin *f*, the vent *g* leading to the upper time-train, the compressed powder-pellet *h*, the lower time-train *k*, the compressed powder-pellet *m*, in the vent *o*, leading to the powder-magazine *p*.

(3) The upper ring *c* is prevented from rotating by the pins *x*.

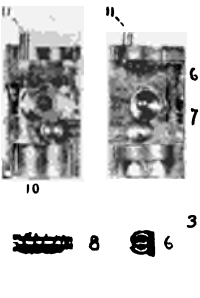
(4) The vent *g* is drilled through the walls of the time-plunger chamber and is exactly opposite a hole in the inner surface of the upper time-train leading to the end of the train from which the direction of burning is anti-clockwise. The hole *j* is drilled through the upper face of the lower time-train ring *d*, to the end of the lower time-train groove from which the direction of burn-

ing is clockwise. The lower time-train ring is movable and is graduated on its outer edge in a clockwise direction from 0 to 21, each full division corresponding to one second time of burning in flight; these divisions are subdivided into five equal parts corresponding to one-fifth second. A radial hole is provided in the lower ring for a pin to be used in setting the fuse. An arrow on the lower flange of the fuse-stock is the datum line for settings.

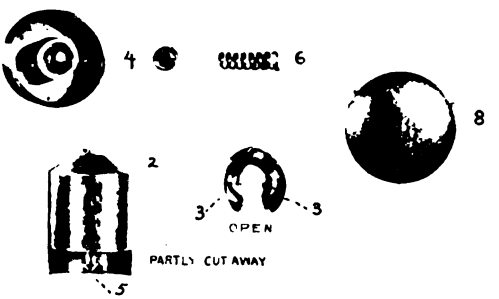
(5) The vent *o* is drilled through the flange of the fuse-stock to the powder-magazine *p*, and leads to the same end of the lower time-train as the vent *j*—that end from which the direction of burning is clockwise when the fuse is at its "zero" setting.

(6) *The action of the fuse as a time-fuse* is as follows: Assume first the "zero" setting as shown in the figure. The time-plunger, a ring resistance-plunger, arms on the shock of firing. The flame from the primer passes out through the vent *g*, igniting the pellet *h*, the end of the upper time-train *i*, down through the vent *j*, to the end of the lower time-train *k*, and thence through the vent *o* to the magazine *p*. It will be seen that for the "zero" setting of the fuse the origins of both upper and lower trains are in juxtaposition. Assume any other setting, say 12 sec. The vent *j* has now changed its position with respect to the vent *h*, leading to the beginning of the upper time-train and the vent *o*, leading to the powder-magazine *p*, both of which points are fixed by the angle subtended between the "zero" and the 12-sec. settings. The flame now passes out through the vent *g* and burns along the upper time-train in an anti-clockwise direction until the vent *j* is reached, when it passes down to the beginning of the lower train and burns back in a clockwise direction to the position of the vent *o*, whence it is transmitted by the pellet *m* to the magazine *p*. For the 21-sec. setting the flame burns the length of both trains. As the trains do not extend all around the fuse, the solid part between the ends of the trains is utilized to obtain a safety-setting. When this point marked "S" is brought opposite the arrow on the lower flange of the fuse, the vent *j* is covered by the solid metal between the ends of the upper train, and the vent *o* is covered in a similar manner by the lower or movable ring.

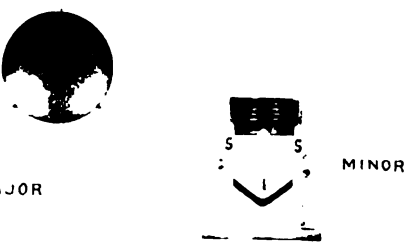
(7) *The percussion element* consists of the primer *r* and the new centrifugal plunger *q*. The plunger is in two parts held to-



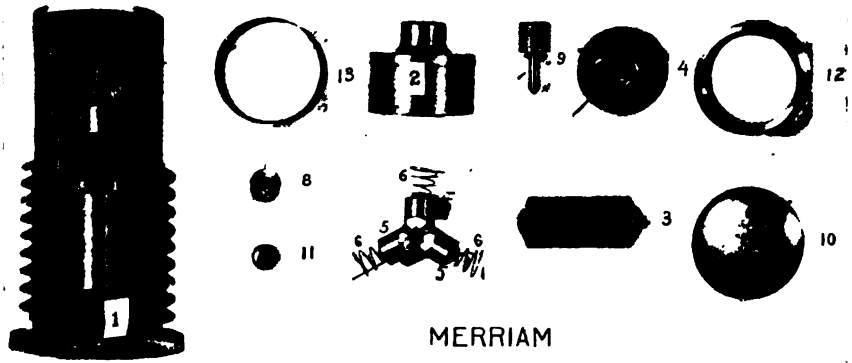
WILSON-LYNCH



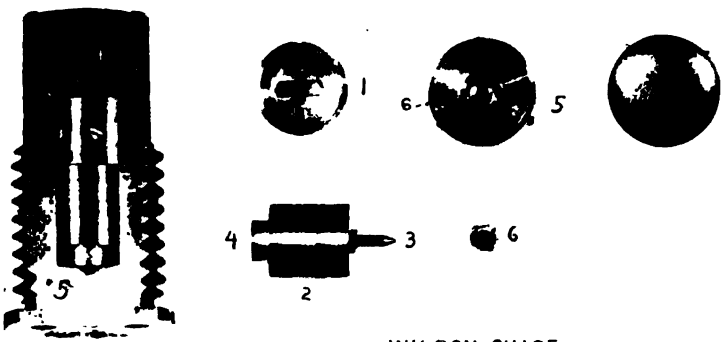
WATSON



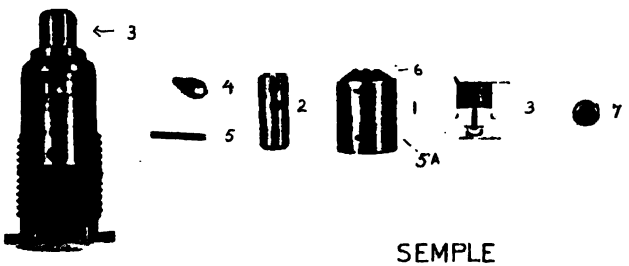
NAVY BASE



MERRIAM

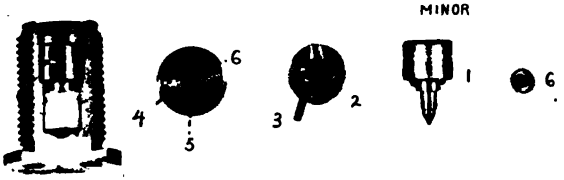


WILSON-CHASE



SEMPLE

MINOR



WILSON-CHASE

MINOR

USES.—BASE-PERCUSSION FUSES.

gether by the bolt 1, and spring 2. When the fuse attains 2500 revolutions the plunger opens out and the cross-pin 4 pulls the point 3 to an upright position, so that upon impact the plunger will fly forward and the point will strike and explode the primer.

19. Frankford Arsenal 15-sec. combination-fuse.—This fuse, shown in Plate VIII, is no longer being manufactured, though a number bought from the army are in service. The action of the fuse is as follows:

(1) *As a time-fuse.*—A hole is punched through the cover *e*, the time-train *c*, and the lead cone *d* at the point in the cover corresponding to the number of seconds desired. Just before loading, the safety-pin *i* is removed. This allows the time-plunger *h* to rest on the fuse-body, where it is held by the split-ring spring *h'*. By shock of discharge the split-ring spring is expanded and the plunger forced to the rear, the primer *r* in the plunger, striking the point *m* and exploding. The flame from the primer passes through four radial holes *s* and ignites the ring of compressed powder *b*. The only vent for these gases is the punched hole, and they ignite the time-train *c* at that point. The latter burns and ignites the powder in the tube *j* and the magazine *k*. The flame from the magazine-charge passes through the percussion primer-plug *l* and percussion-plunger and ignites the bursting-charge in the shrapnel.

(2) *As a percussion-fuse.*—By shock of firing the sleeve *n* is carried to the rear. The split-ring *t* opens out and is forced back into the groove around the rear end of the plunger *o*, where it springs into place. The plunger *o* and sleeve *n* are now locked together and the point exposed. On impact both fly forward and explode the primer-cap *l*. The percussion part of this fuse is similar to that of the old Frankford Arsenal base-percussion fuse, which was discarded by the navy as it would not stand the drop-test.

20. Frankford Arsenal primer-caps.—(1) These caps, which are considered to be safer than the fulminate ones, consist of the following ingredients in the proportions named:

Chlorate of potash	50.54
Sulphide of antimony	26.31

Sulphur	8.76
Ground glass	12.39
Shellac	2.00

(2) The thoroughly pulverized ingredients are mixed dry, and alcohol is added to dissolve the shellac. The percussion pellets are formed by pressing the mixture while in a plastic state into the percussion-primer recess. Upon the evaporation of the alcohol the shellac causes the pellet to adhere strongly to the metal of the recess. This primer-cap is thought to be much safer for handling than the fulminate caps.

21. Specifications for shrapnel-fuses.—Shrapnel-fuses shall be made in accordance with drawings approved by the Bureau.

(1) The fuse-stocks, caps, adjusting-ring, and plungers shall be of any good commercial brass composition and shall be finished as well as the best machine methods permit.

(2) The time-train shall be of suitable composition enclosed in a uniformly drawn or rolled lead tube.

(3) The parts of the fuse shall be subject to a visual inspection only, with the exception of the shank-thread, which must qualify in approved standard gauges. The inspector, however, shall witness the shop-tests of time-trains as a means of satisfying himself as to their uniformity.

(4) The fuses shall be presented for test in lots of 1000, and from each lot ten fuses shall be selected by the inspector for test as follows:

(5) Two of the fuses shall have their percussion elements tested either by dropping loaded and fused shrapnel in an explosion chamber, or by firing through a $\frac{8}{16}$-inch steel plate or its equivalent. Three shall be given the dropping test for safety from a height of 30 feet. The remainder of the fuses shall be fired with service-charges over a range to test the time element.

(6) For the time-test the fuses will, generally, be cut for times between 2 and 8 seconds, and the elapsed time between the appearance of smoke at the muzzle and the explosion of the projectile shall be noted by chronographs or stop-watches. The least time noted shall be taken as the true time, and this must not differ more than one-third of a second, plus or minus, from the time for which the fuse was set.

(7) The failure of any fuse tested to function properly, or a discrepancy of more than one-third of a second between the set time and the burning time, shall be sufficient cause for the rejection of the lot.

CHAPTER XXX.

STOWAGE AND SUPPLY OF AMMUNITION.

1. Ammunition-rooms, magazines.—With the exception of the detonators and dry gun-cotton primers for torpedoes, all ammunition, of whatever character, is stowed in specially constructed rooms set apart for that purpose alone; a few projectiles are often stowed in racks around the gun-emplacements or below decks, where they can be expeditiously supplied to all guns in emergencies. The ammunition-rooms are commonly distinguished in name by the kind of ammunition they contain as well as by their regular numbers; for example, compartment A 37 M is one of the forward 12-inch magazines; compartment D 33 M is the "small-arms" magazine.

FIG. 1. ART. 2.

2. Flooding and draining.—All ammunition-rooms are watertight compartments and are placed below the water-line; to prevent explosions in case of fire below decks, arrangements are made for admitting sea-water to each room; such rooms as are unavoidably built *above* the water-line have flood-pipes leading from the fire-main. The *flood-pipe,* of a size sufficient to fill the empty magazine in about twenty minutes, leads from the outer skin of the ship below the water-line directly to a *flood-valve,* which is worked either in the magazine itself or from the berth-deck. A spindle leads from the valve to a *plate* on the berth-deck and ends in a square section on which is shipped a large key for turning the valve; the key or wrench is kept near at hand in

a locked rack, the key of which is kept with the magazine keys. The deck-plate is stamped with the name and the compartment number it floods and an arrowhead indicates the direction that opens the valve. In addition, a specially shaped plate, with a red ground, secured to the beam above, gives the same informa-

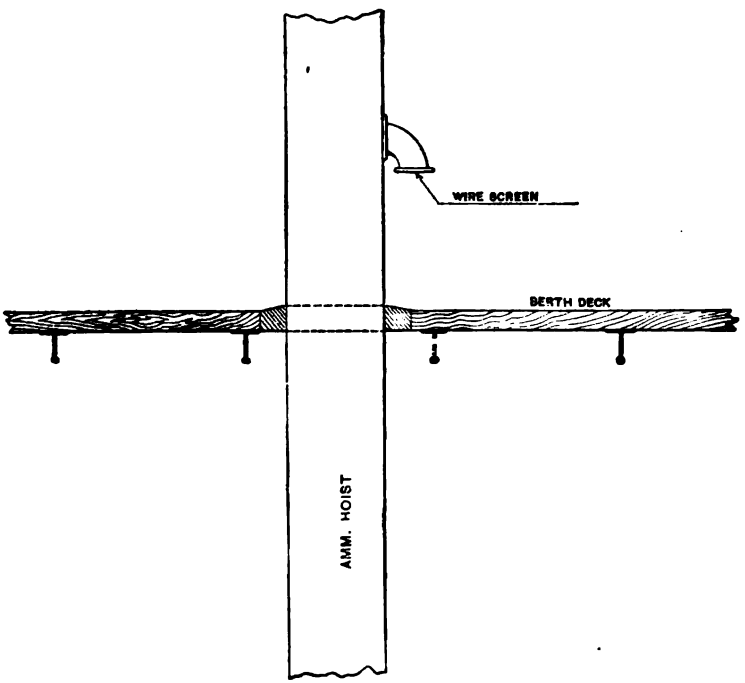


FIG. 2. ART. 3. AMMUNITION-HOIST AS VENTILATOR.

tion (see figure). The air escapes from the magazine through the exhaust *ventilating-duct;* if none is fitted, a special escape-pipe is provided to allow the room to fill. Those compartments flooded from the fire-main have *relief-valves* to prevent the accumulation of a pressure that would make the bulkheads collapse.

Ammunition-rooms in the hold *drain into bilge-wells*, from which suction-pipes lead to drain manifolds. Upper compartments sometimes have individual drain-pipes to drain wells or

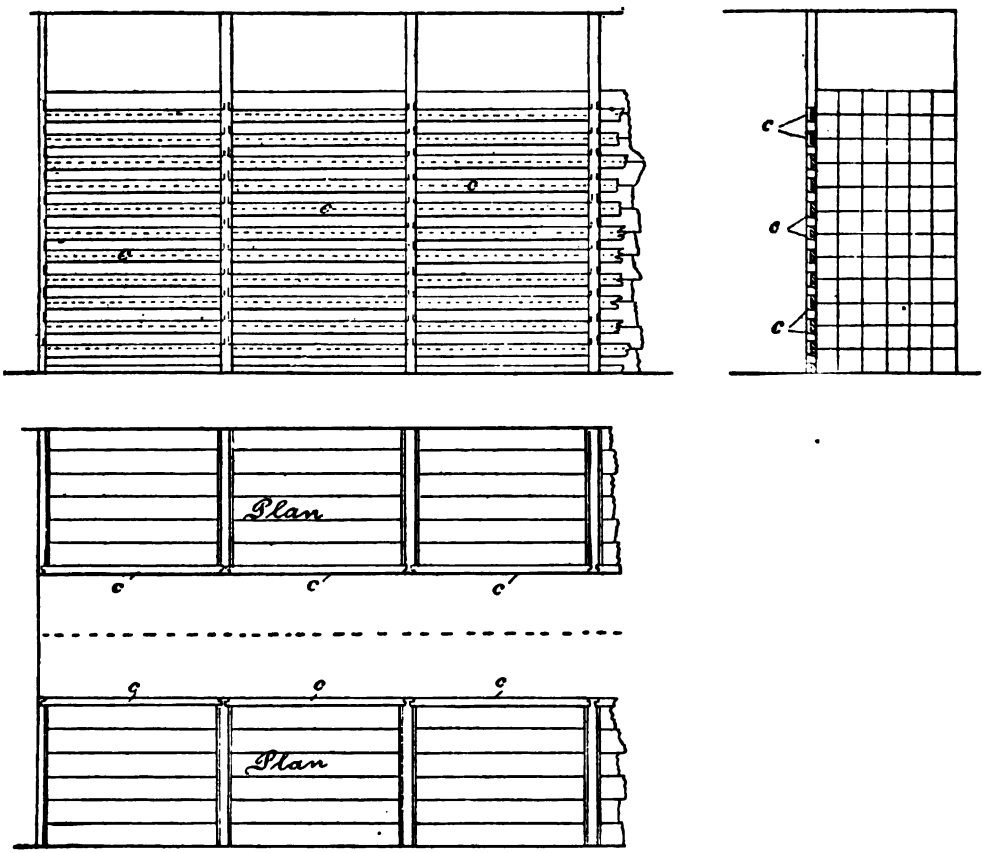
lower compartments; in other cases, they can be freed of water, that happens to find its way into them, only by portable pumps.

3. Ventilation.—*The adoption of a smokeless powder which, in the process of manufacture, is colloided with a very volatile liquid, makes the subject of ventilation a very important one;* the ether-fumes are inflammable and must be carried off and, in addition, the powder must be kept cool. To this end, every ammunition-room is fitted to receive, directly from the ship's artificial ventilating system, a supply sufficient to renew the air once in about eight minutes. A natural exhaust-pipe of greater area than the supply-duct is placed in each room as far away from the supply as possible; the upper end is carried up at least above the berth-deck and terminates in a gooseneck covered with wire-mesh. When ammunition-hoists open directly into the magazine, the trunk of the hoist itself is used for natural exhaust ventilation (see figure); a gooseneck outlet, covered with wire-mesh, is fitted at a height above the berth-deck. Piping in ammunition-rooms is generally of brass.

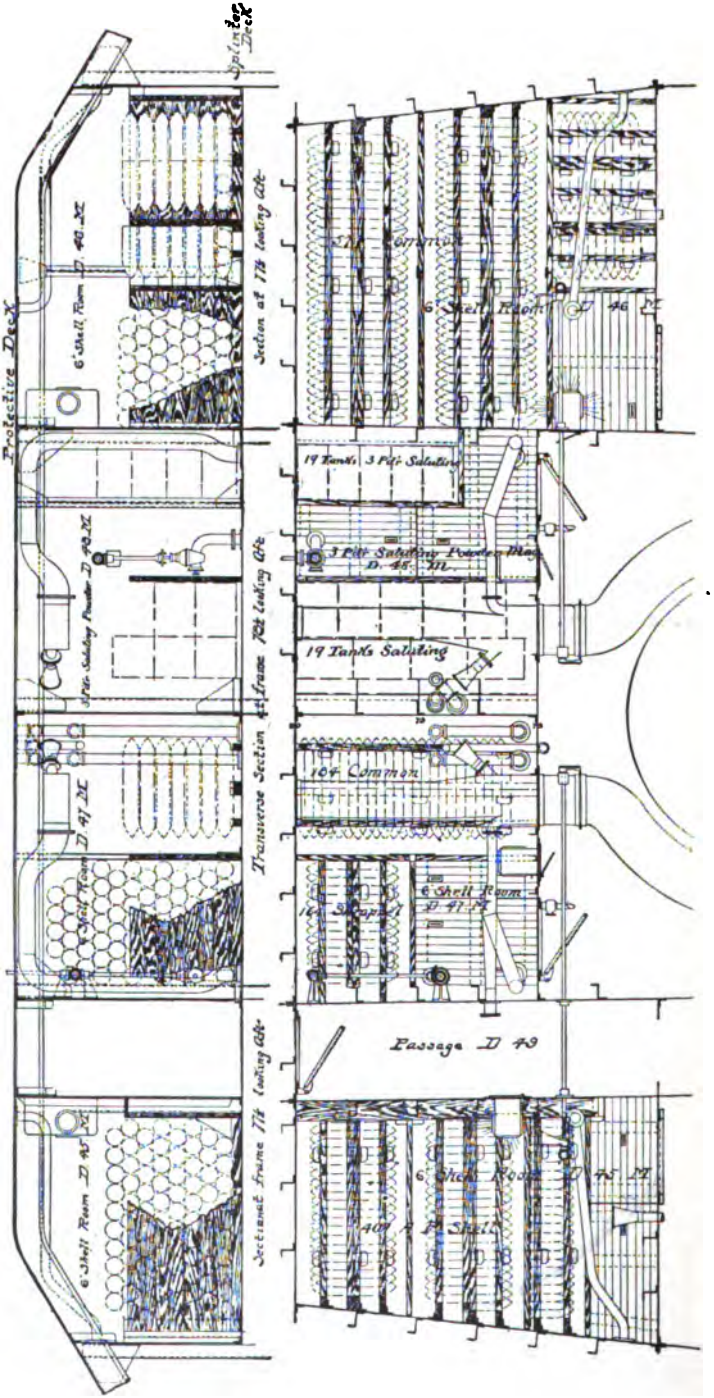
4. Lighting.—Each magazine and shell-room is lighted by one or more *light-boxes,* of standard navy pattern, which throw light in three directions through round ports covered with double glass plates. The boxes are watertight and are separate compartments opening *only* from the deck above or from some passage or compartment outside the magazine. The light-boxes each contain *incandescent lamps* and are arranged to burn *candles* if the lamps fail; in the latter case, enough water to cover the bottom should be poured into the light-box.

5. Stowage, location of magazines, etc.—The ammunition-rooms, as a rule, form two groups, one in each end of the ship, next forward and abaft the engine and boiler spaces. To the greatest extent practicable, the ammunition-compartments are below the water-line and are always beneath the protective-deck for protection and for facility in flooding; their arrangement must be such that the contents may be gotten out and sent to the guns expeditiously.

6. If the groups of magazines, etc., contain any rooms that are next to boiler or engine-rooms, they are separated from such



STOWAGE OF 4-INCH, 5-INCH AND 6-INCH R. F. AMMUNITION BOXES.


Protective Deck
Transverse Section at Frame 70 t looking Aft
Section at 174 looking Aft
Sectional Frame 174 looking Aft
6" Shell Room D 46 M
6" Shell Room D 47 M
6" Shell Room D 48 M
6" Shell Room D 45 M
19 Tanks 3 Pdr. Salutes
3 Pdr. Saluting Powder Mag. D. 48 M.
19 Tanks Saluting
104 Common
6" Shell Room D 47 M
Passage D 49
6" Shell Room D 45 M
40 P. P. Shell

6-IN. SHELL ROOMS OF U. S. S. MAINE.

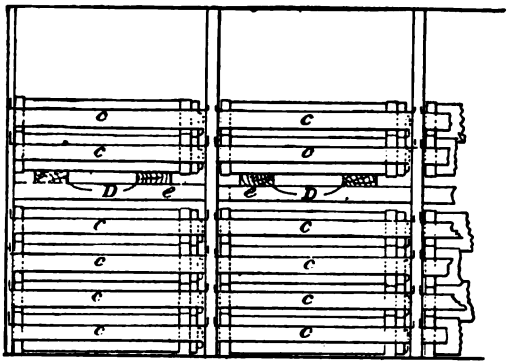
sources of heat by double bulkheads, separated by a narrow air-space which has an outlet to the upper deck.

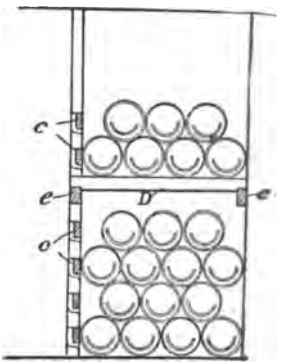
7. *The problem of location* varies greatly for the different designs of ships. In large ships which have splinter-decks, the two groups of ammunition-rooms are connected by long-wing compartments on this level, called the *ammunition-passages;* many of the rooms open on these passages, which are just inside and above the machinery spaces, and they are particularly useful in *supplying* ammunition to the battery.

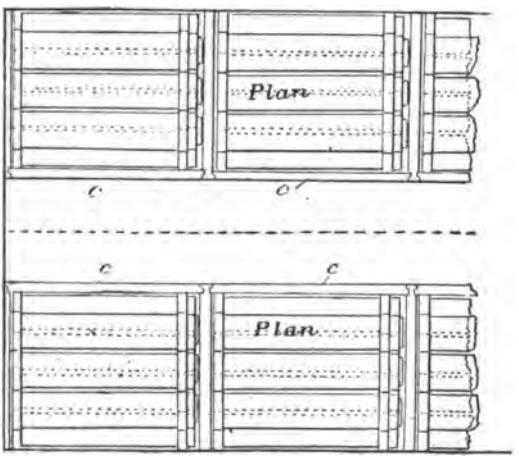
8. **Ready magazines.**—There is sometimes a third group of magazines about midway between the two main groups, which open on the ammunition-passages and supply the waist-guns; these rooms are small and are called the "ready" or auxiliary magazines.

9. **The ammunition-rooms of turret-guns** open into a common *handling-room,* beneath the turret, from which the hoists convey their contents to the guns. For other magazines and shell-rooms the same plan is followed where space permits; the ammunition-passages are really *handling-rooms.* The shell-room doors swing into the handling-rooms and are kept open while projectiles are being supplied; but the magazine-doors are kept closed and the charges are passed through small openings which are in turn closed by shutters; this arrangement is to prevent, as far as possible, an explosion in the handling-room from reaching the magazine. When there is no space for handling-rooms, the hoists open directly into the magazines and shell-rooms; it is, in this case, usual to place the hoisting-motors and controlling-panels outside, to prevent any possibility of an explosion by the ignition of ether-fumes from electric sparking. All magazines are floored with ash gratings; the wood used in the racks and bins for the ammunition is of non-fireproof yellow pine.

10. **Rapid-fire ammunition** is stowed in its boxes in *bins* in which the charges of the same character are kept separate; thus, in a 3-inch magazine, one bin will contain armor-piercers, another common shell, etc. Also, the different calibers are stowed in separate magazines; miscellaneous ammunition, such as 1-pounder, .30-caliber, machine-gun, rifle, and revolver ammunition is stowed together. These magazines are frequently called "fixed







STOWAGE OF 6-INCH POWDER TANKS.

ammunition-rooms"; the boxes are piled in tiers as is most convenient in transferring to the hoist. The sides of the bins are formed from removable battens shipping in vertical channels (see Plate I).

11. Projectiles for other than R. F. guns are stowed in separate *shell-rooms.* The bins are strong and the projectiles are stowed in bulk in *tiers,* the same kinds being kept together. If there are two rows in the same bin, they are stowed base to base, and, in any case, the bins are lined with wood against which the sharp noses bring up (see Plate II). Overhead rails, for the cars of the differential lifting-purchases, lead from the bins of the large-caliber shell-rooms through the doors to the hoists; smaller projectiles are transferred by hand. In the few ships in which hand-whips only are used, the projectiles are often stowed with straps running longitudinally around each and seized together to form an eye at the nose, into which the whip hooks; this is a convenient, though expensive, way of handling projectiles during shipment. All 10-inch, 12-inch, and 13-inch projectiles are shipped in strong boxes from which they are removed before stowing in the shell rooms.

12. Powder-tanks are also stowed in bins, usually on their sides (see Plate III). The older cases are not strong and, as shown, can be stowed only a few tiers high; in this case, horizontal wood battens (*D*) support the upper layers. Wooden battens run along the sides of the new tanks and so strengthen them that they may be piled up to the deck-beams. Tanks should be stowed so that their contents can be removed without disturbing them; it is usual to arrange them, particularly those for the turret-guns, with their heads to the passage. The bins are built up from stationary vertical channels and rolling-boards, which are removed to get at the tanks. Bins are arranged in the different magazines with a view to accessibility in supplying powder to the hoist and, where necessary, alleys are run between them. While the ship is rolling, projectiles, powder-tanks, and charges are more secure if stowed parallel with the keel, but the tanks and charges should be perpendicular to the passages. It has been found that when the tanks are stowed on end, the powder settles and stretches its bags; this has been so troublesome that the charge could be gotten into the gun only with great difficulty.

Name.	Comp't.	Location.	Side.	Tanks. 12" A. P. Capped.
For'd 12" Magazine	A. 33 M.	Plat DK 20-22	S	15
" 12 "	" 34 "	" " 20-22	P	16
" 12 "	" 35 "	" " 20-23	S	26
" 12 "	" 36 "	" " 20-23	P	26
" 12 "	" 37 "	" " 23-27	S	65
" 12 "	" 38 "	" " 23-27	P	65
" 12 "	" 42 "	" " 28-30	S	16
" 12 "	" 42 "	" " 28-30	P	13
After 12 "	D. 19 "	" " 70-72	S	14
" 12 "	" 20 "	" " 70-72	P	14
" 12 "	" 21 "	" " 70 73	S	42
" 12 "	" 22 "	" " 70-73	P	42
" 12 "	" 23 "	" " 73-77	S	49
" 12 "	" 24 "	" " 73-77	P	49
" 12 "	" 27 "	" " 78-80	S	15
" 12 "	" 28 "	" " 78-80	P	15
For'd 12 Shell Room	A. 39 "	" " 27-30	S	24
" 12 " "	" 40 "	" " 27-30	P	24
After 12 " "	D. 25 "	" " 77-80	S	24
" 12 " "	" 26 "	" "	P	24
For'd 6 Magazine	A. 21 "	Hold 23 27	S	
" 6 "	" 25 "	" 20-30	S	
" 6 "	" 26 "	" 20-30	P	
After 6 "	D. 11 "	" 70-80	S	
" 6 "	" 12 "	" 70-80	P	
Midship 6 Aux. Magazine	B. 47 "	Sp'l DK 41-47	S	
" 6 " "	" 48 "	" " 41-47	P	
" 6 " "	" 49 "	" " 47-53	S	
" 6 " "	" 50 "	" " 47-53	P	
For'd 6 Shell Room	A. 19 "	Hold 20-23	S	
" 6 " "	" 20 "	" 20-23	P	
" 6 " "	" 22 "	" 23-27	P	
" 6 " "	" 23 "	" 27-30	S	
" 6 " "	" 24 "	" 27-30	P	
After 6 " "	D. 45 "	Sp'l DK 77-80	S	
" 6 " "	" 46 "	" " 77-80	P	
" 6 " "	" 47 "	" " 78-80	S	
8 P'd'r Saluting Powder Magazine	" 48 "	" " 78-80	P	
For'd 8" & 8 P'd'r Magazine	A. 47 "	" " 23-27	S	
" 8 " 8 " "	" 48 "	" " 23-27	P	
After 8 Magazine	D. 45 "	" " 73-77	S	
" 8 "	" 46 "	" " 73-77	P	
Small Arms Magazine	" 33 "	Plat " 80-83	S	
1 P'd'r & 8 P'd'r Magazine	A. 47 "	Sp'l " 20 23	S	
1 " " 8 " "	" 48 "	" " 20-23	P	
Torpedo War Heads	" 6 "	Hold 11-13	P	
Submarine Mines	" 8 "	" 13-16	P	
Possible Stowage				482 96
Allowance Ammunition				480 96

SUMMARY OF STOWAGE.

Amm.			6″ Amm.						Fixed Amm.																			
Common Shell.	Shell Dummy.	¼ Charge Dummy.	Charge.	A. P. Capped.	Common Shell.	Shrapnel.	Shell Dummy.	Charge Dummy.	3″ (50 Cal.) Fixed Ammunition.	3″ (50 Cal.) Dummy Cartridges.	3 P'd'r Fixed Ammunition.	3 P'd'r Saluting.	3″ Field Gun, Fixed Ammu.	1 P'd'r Heavy Fixed Ammu.	1 P'd'r Heavy Feed Boxes.	3 P'd'r Drill Cartridges.	1 P'd'r Drill Cartridges.	30 Cal. Rifle Ball Cartridges.	30 Cal. Rifle Blank Cartridges.	30 Cal. Rifle Dummy Cartridges.	38 Cal. Revolver Ball Cartridges.	45 Cal. Rifle Ball Cartridges.	22 Cal. Rifle Ball Cartridges.	Tanks 3 P'd'r. Saluting Powder.	Torpedo War Heads.	Submarine Mines.	(30 Cal.) Colt Automatic.
			236					15																			
			771																								
			760																								
			749																								
			673																								
			733		80																						
			73		80																						
			136		64	21																					
			136		64	21																					
				108	61	49																					
				108	61	49																					
				85	317	293																					
				126	165	91	16																				
				126	241																						
				407																							
					571																						
					184	161																					
			38									19												19			
									99		171																
									99	12	112		18														
									132																		
									198																		
																		150	16	5	13	10	12				
											20			40													
														32		4	3										20
																									48	13	
44			3695	960	1888	694			528		303			72													
44	4	8	3200	960	1920	320	16	15	528	12	300	19	18	67		4	3	150	15	5	13	10	12	19	48	13	20

13. The ammunition-rooms of small ships are simply arranged in two groups in the hold, forward and aft. Of this type the Baltimore carries the following ammunition:

TOTAL STOWAGE.

In Magazine..	6-inch Shells	2160 Rounds
On Deck.....	6-inch "	240 "
In Magazine..	6-inch Charges	2400 "
" " ..	3-inch Ammunition	459 Boxes (including 9 Boxes 3-inch Field-Gun Ammunition)
" " ..	3 Pdr. Ammunition	244 Boxes
" " ..	1 " "	40 "
" " ..	30 cal. Machine Gun	50 "
" " ..	30 " Ball Cartridges	100 "
" " ..	30 " Blank "	10 "
" " ..	30 " Gallery Practice	10 "
" " ..	38 " Ball Cartridges	10 "
" " ..	45 " " "	5 "
" " ..	Common Powder	19 "
" " ..	Primers	1 "

14. This ammunition is handled by one secondary-battery hoist and four 6-inch hoists at each end of the ship.

15. Stowage for battleships.—The stowage and means of supply of the new Maine are shown in the plans on Plate V; her battery consists of four 12-inch, sixteen 6-inch, six 3-inch (50-caliber), two 3-inch field guns, eight 3-pounder, six 1-pounder, and two Colt automatic guns. The allowance and possible capacity of all kinds of ammunition is given in the table on pages 370-371.

16. The magazines and shell-rooms are in three groups—one around the base of each turret and a smaller one in the waist; all are below the protective-deck, the top or crown of which is a little above the water-line.

17. The waist-group comprises two 6-inch charge and shell magazines, designated the "ready" or auxiliary magazines, on each side at the level of the splinter-deck. These rooms, four in number, open on the ammunition-passage which is on the same level. The other two groups are on three flats—splinter-deck, platform, and hold.

18. The 12-inch ammunition rooms (see Plate IV), all on the platform-deck, open into the handling-rooms at the same level. The powder-charges are distributed among eight magazines in the forward group and the same number aft; the projectiles are carried in two shell-rooms forward and two aft.

19. Besides the 6-inch auxiliary magazines in the waist, there are in the hold five other magazines for 6-inch charges—three forward and two aft. A few 6-inch projectiles are stowed in the auxiliary magazines and around the gun-emplacements, but the bulk of them is carried in five shell-rooms in the fore-hold and three on the splinter-deck aft. Some 6-inch charges are stowed in the saluting powder-magazine.

20. The 3-inch and 3-pounder ammunition stows in two fixed ammunition-rooms forward and two aft—all on the splinter-deck. One-pounder ammunition and a small amount for 3-pounders and Colt automatic guns is stowed in two magazines on the forward splinter-deck. *Small-arm ammunition* has a room by itself just abaft the after 12-inch magazines.

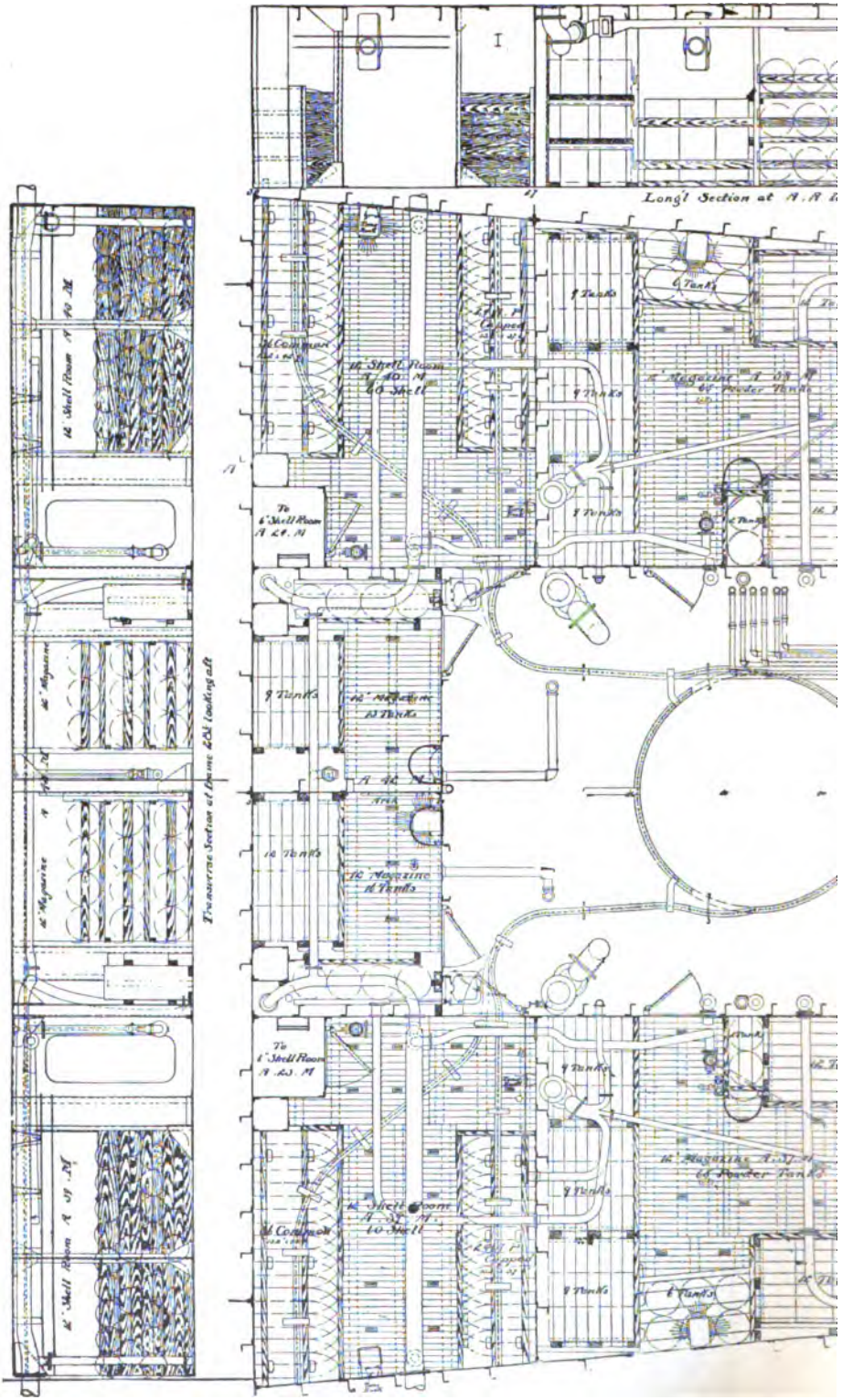
21. Gun-cotton magazines.—The Maine has two under-water torpedo-tubes in a compartment (which also stows the allowance of torpedoes) on the platform-deck forward of the magazine group; underneath it on the port side are the two *gun-cotton magazines* (see plate).

22. *The ammunition-passages on the splinter-deck* may be utilized to stow extra projectiles and, with proper precautions, a supply of charges as well, but they should not be kept there for a long period; unless used first, this would be likely to interfere with handling ammunition as the space is already somewhat restricted.

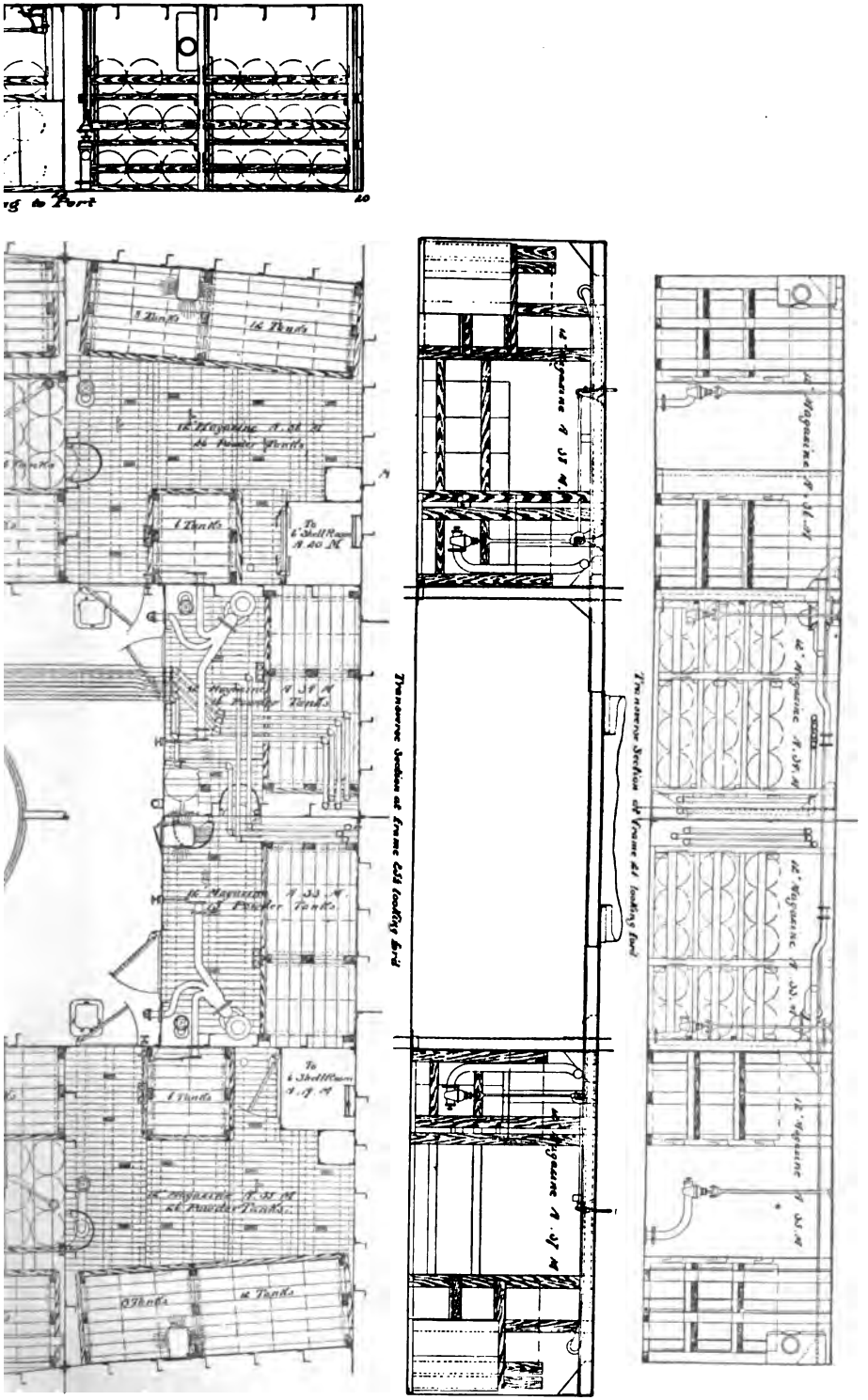
AMMUNITION SUPPLY.

23. For the efficient use of a ship's battery in action, the supply of ammunition is next in importance to the correct use of her guns; the excellence of the gun-pointers and crews will avail nothing unless they can receive the ammunition in exactly the proper way.

24. Safety.—Save for a few projectiles, it is unsafe to stow any ammunition near the guns; in fact, we have seen that it is imperative to stow it *below* the water-line in certain places, which may be a long distance from some of the guns. The problem, then, which varies in its intricacy in each class of ships, is to maintain a supply of ammunition to each gun—firing several rounds per minute—as fast as it is needed, without allowing it to



FORWARD 12-INCH MAGAZINES AND



SHELL ROOMS OF U. S. S. MAINE.

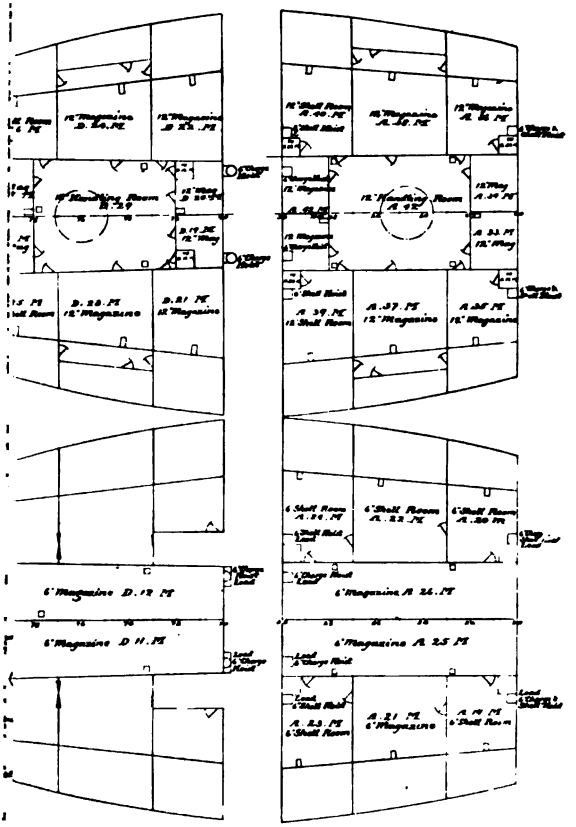
accumulate on deck, as, for instance, when the gun, to which a particular chain of supply leads, is silenced. All practicable precautions against powder explosions from the enemy's fire must be enforced.

25. Obviously, the simplest and surest solution of the problem is to install a magazine and shell-room directly beneath each gun, with hoists leading upward to it. This would involve placing a line of magazines along each side of the ship, extending the whole length of the machinery spaces, which cannot be done because many rooms would be too near sources of heat, and the space is not available. These restrictions, which complicate the problem on board ship, do not affect the question of gun installation on shore, where space and weight are unlimited.

26. This ideal arrangement of individual magazines and hoists is, in general, attained only for turret-guns which, as it happens, are mounted over spaces available for magazines; the tendency, however, is to provide a hoist for each main-battery gun and a sufficient number for the smaller pieces; the hoists cannot lead very obliquely, and in some cases ammunition must be transported by hand over considerable distances, both below and on the battery decks; however, it is the best that can be done, and the difficulty exists in all navies.

27. Ammunition stowage and supply is a problem to which the designer devotes much thought; but when he has exhausted his ingenuity in the finished ship, the question of *efficient supply* is only partially solved, because the more important part is concerned with the *personnel* rather than with materiel. It remains for the "Powder-Division" (which contains many good men, and many not suitable for work at the guns) to manipulate the machinery of supply to the best advantage. The best thought of the officers in direct command is needed at this point, and complete success will come only when all the details have been minutely and patiently worked out. Care in stationing every man according to his fitness will often give good results from a manifestly imperfect system.

28. Ammunition-hoists for turret-guns were described in a previous chapter. Hand-whips for getting up ammunition are



relied upon in some of the older ships and for a few supply-chains of minor importance in later designs. In most other cases, a power-hoist, which works somewhat like a grain-lift in an elevator, is employed. Plates VI and VII show a 5-inch R. F. hoist; the same general system is used for all charges and projectiles, secondary-battery ammunition-boxes, etc.

29. *A steel trunk* (5) extends from the main-deck through the protective- and splinter-decks to the platform on which the magazines for 5-inch R. F. ammunition are situated. The trunk has two compartments, divided by a partition in the direction of its length; at each of its upper and lower ends a pair of *sprocket wheels* (2), which carry endless *sprocket chains,* are fitted. Attached to the sprocket chains are five carriages (7), fitted with rollers, which support the ammunition-boxes. Power is applied by suitable gearing from an *electric motor* (1) to the axle of the lower pair of sprockets. Hand-gear, for use in case the motor breaks down, is also fitted.

30. At the lower end of the trunk is fitted a *loading-table* (3) on which the ammunition-boxes are first landed, on end; guides (4), at the sides of the trunk, insure accurate placing of the boxes. The boxes are picked up by the carriages as they pass the table and carried up, resting on the carriages and against the partition between the compartments of the trunk. Just above the protective- and splinter-decks, *pawls* (6) are fitted which are tripped as the boxes pass and drop back into place as the carriages pass, thus preventing the fall of an ammunition-box below the pawl, in case of accident. A pawl (6) with a light spring is attached to the front side of the trunk at the upper end to assist in tipping the ammunition-box on the rollers at the top of the trunk; the carriage passes the upper sprocket-wheels, pushes the box on to the deck, and then continues down the other compartment of the trunk on its return to the magazine.

31. By this arrangement, when one box has just started from the magazine, one is half-way up the trunk and one is about to be delivered on the main-deck; two carriages are on their way down to the magazine.

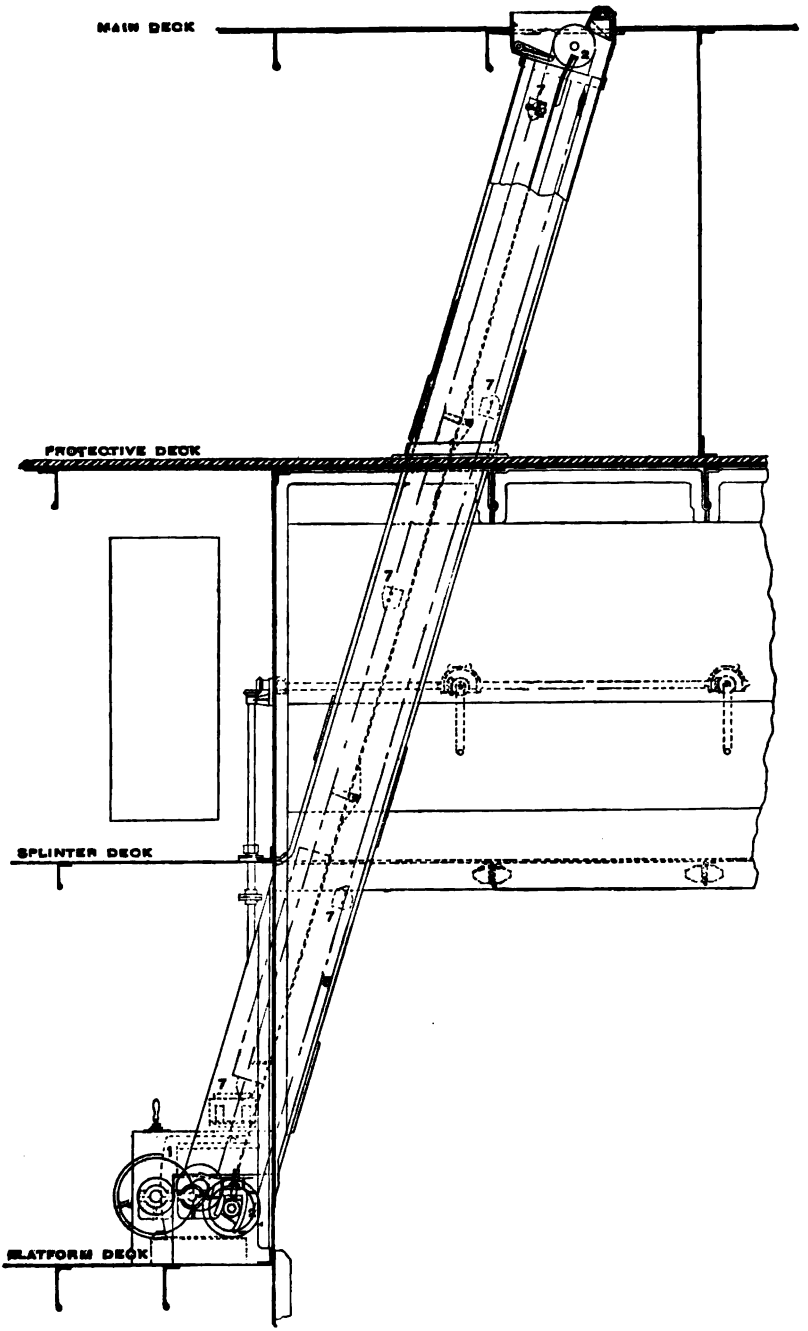
SUPPLY SYSTEM OF THE MAINE.

32. The supply system of the Maine is shown in Plate V. The hoists for the 12-inch guns lead upward from the handling-rooms as previously described; those for the other kinds of ammunition are of the same general type as the 5-inch hoist of Plates VI and VII.

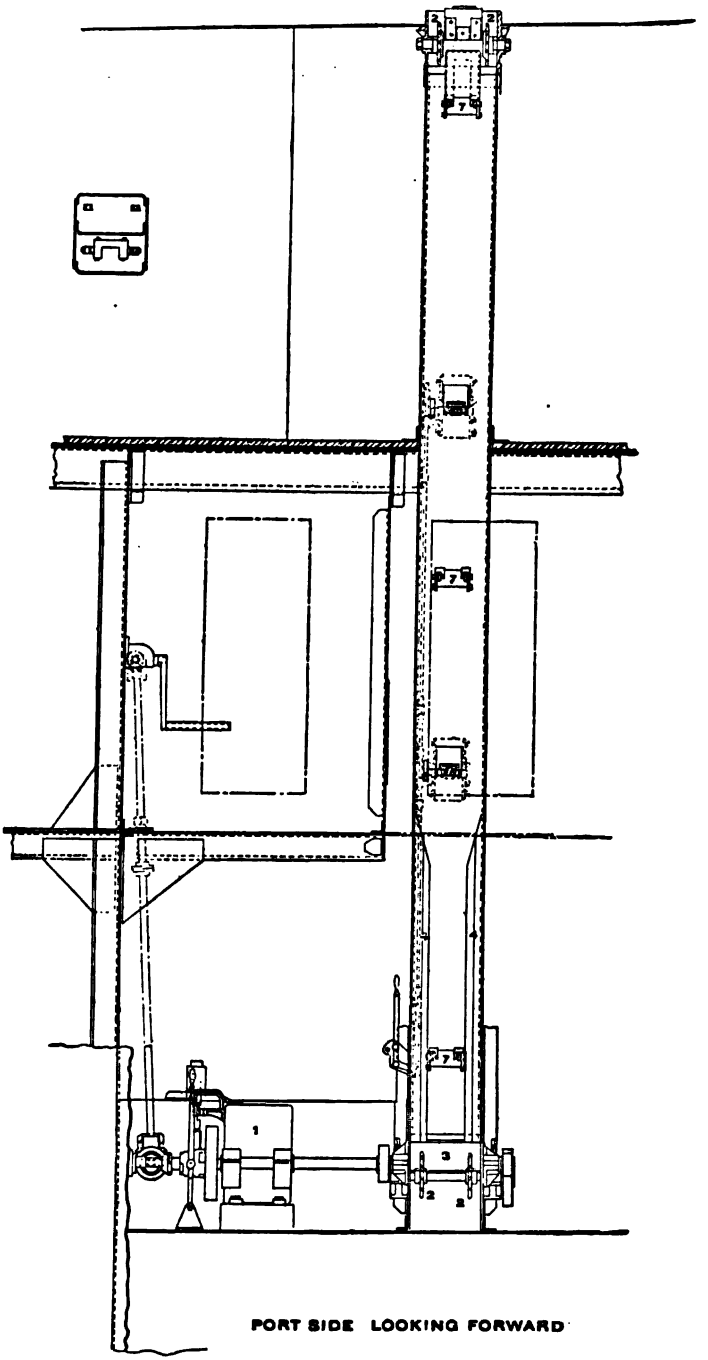
33. The four 6-inch guns on the upper deck are each supplied by a charge- and shell-hoist which loads in the ammunition-passage and delivers near the gun it supplies. The forward pair of main-deck 6-inch guns (which, being well forward of the turret, do not appear in the plate) also each have a charge- and shell-hoist which leads from the forward end of the forward 6-inch magazine group and delivers on the main-deck at some distance from the guns. In addition to the six already mentioned, there are ten 6-inch pieces mounted in broadside on the main-deck within the citadel. Ammunition is supplied to these guns by two charge- and shell-hoists which lead from the ammunition-passages and deliver at about the center of the battery, and by four charge- and four shell-hoists leading from the forward and after 6-inch magazines and shell-rooms and delivering at each end of the citadel. It is not likely that both sides of a ship will be engaged at the same time—at least not for a long period—and all hoists of the unengaged side may be utilized at need for the supply of the engaged guns; in fact in this ship the hoists of both sides *are* needed for one battery.

34. The 3-inch ammunition is delivered to its guns on the bridge deck by two hoists leading from the *port* ammunition passage and delivering at that level. On each side are two hoists for sending up 3-pounder and 1-pounder ammunition in its boxes; these four hoists are all loaded in the ammunition-passages. The after-ones deliver on the upper deck; ammunition for the guns on the after-bridges and in the top is hoisted from the upper deck by hand-whips. The starboard forward hoist delivers on the bridge-deck and the port one on the upper bridge; from here it is whipped up to the top by hand.

35. A handling-table, with accessories, for 8-inch turrets is shown in Plate VIII. In many of the earlier turrets of this size



5-INCH AMMUNITION HOIST, PORT SIDE, LOOKING OUTBOARD.



PORT SIDE LOOKING FORWARD

Mark.	Name.	Description.	Material.	Remarks.
1	Motor	To specification		3¾ H. P. at 375 revs.—Shunt wound, 160 volts
2	Sprockets	9.659″ Pitch-diam.: 12 teeth.	Cast steel	
3	Load'g-table		Naval brass	
4	Guides		Wood	
5	Trunk		Steel	
6	Pawl		Cast steel	Fitted with spiral spring.
6	Pawls		Cast steel	
7	Carriages	Fitted with brass rollers	Cast steel	Number of carriages on each hoist.

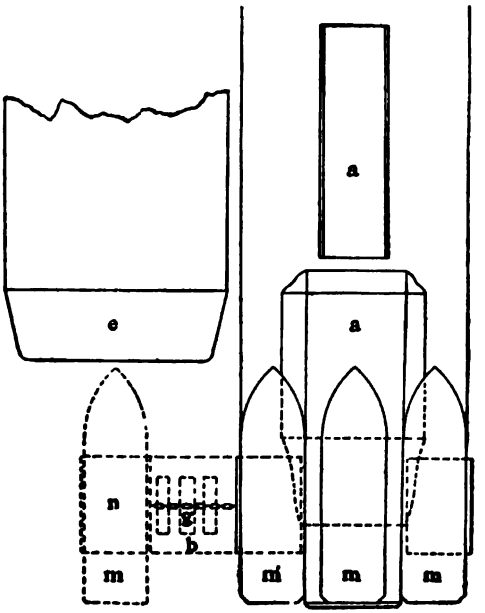


FIG. 1. Top View.

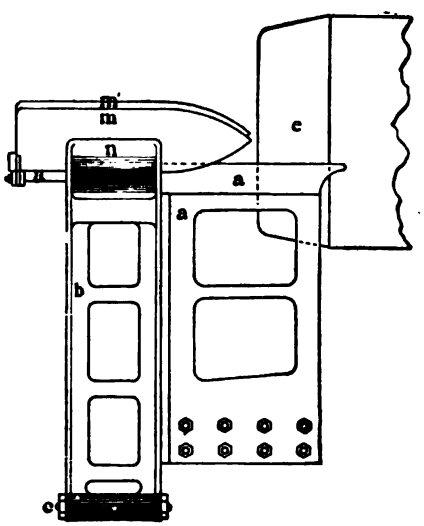


FIG. 2. Side View.

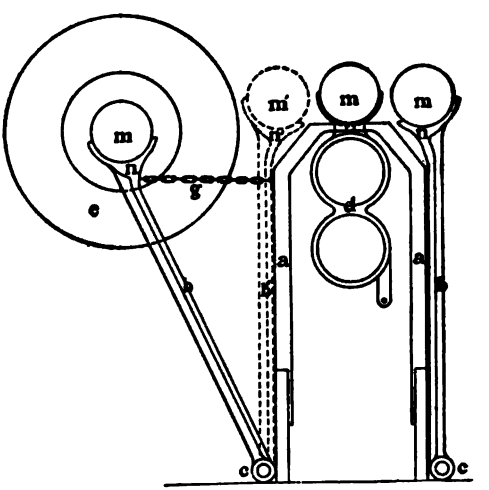


FIG. 3. Rear View.

UPPER END OF AMMUNITION HOIST FOR 8-INCH TURRETS.
["INDIANA TYPE"]

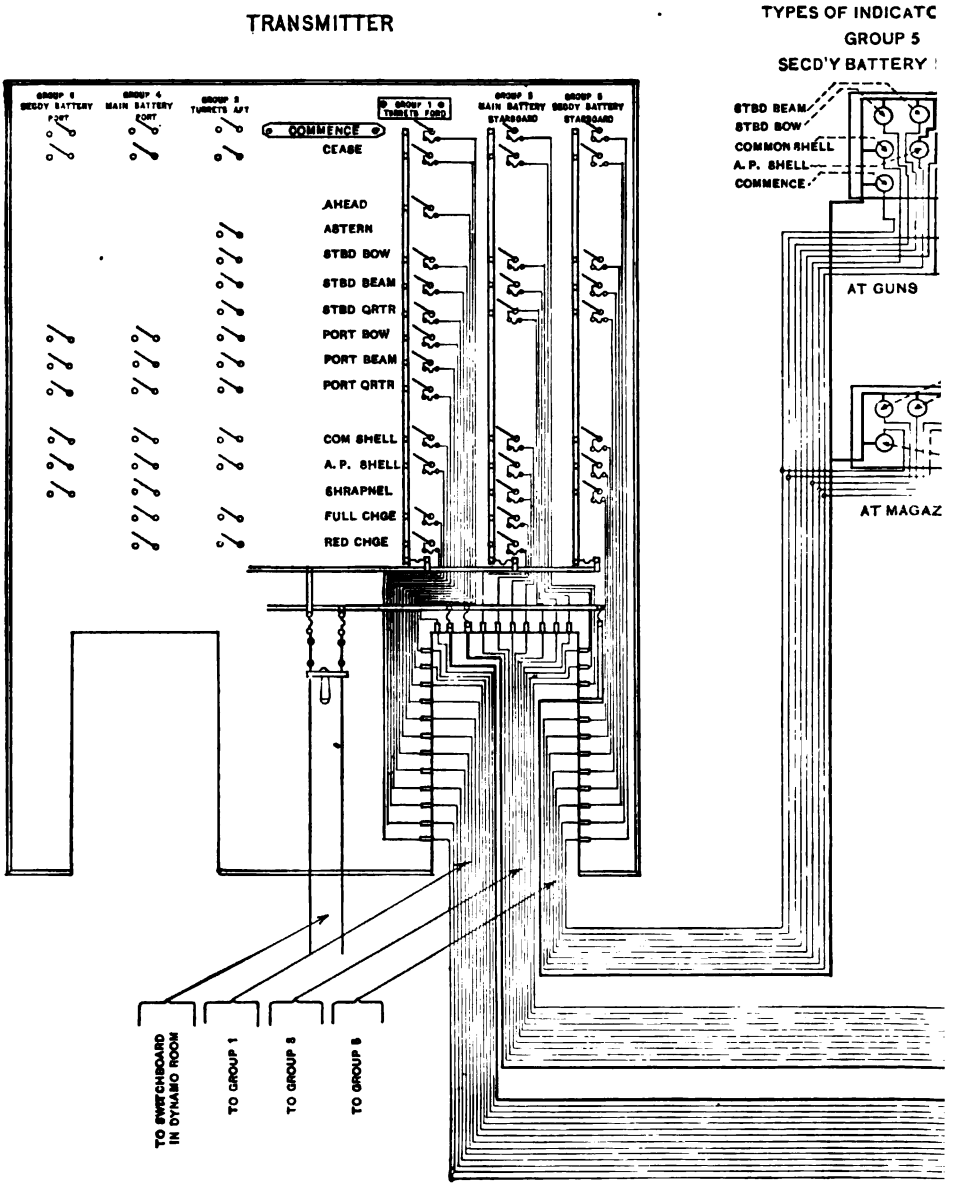
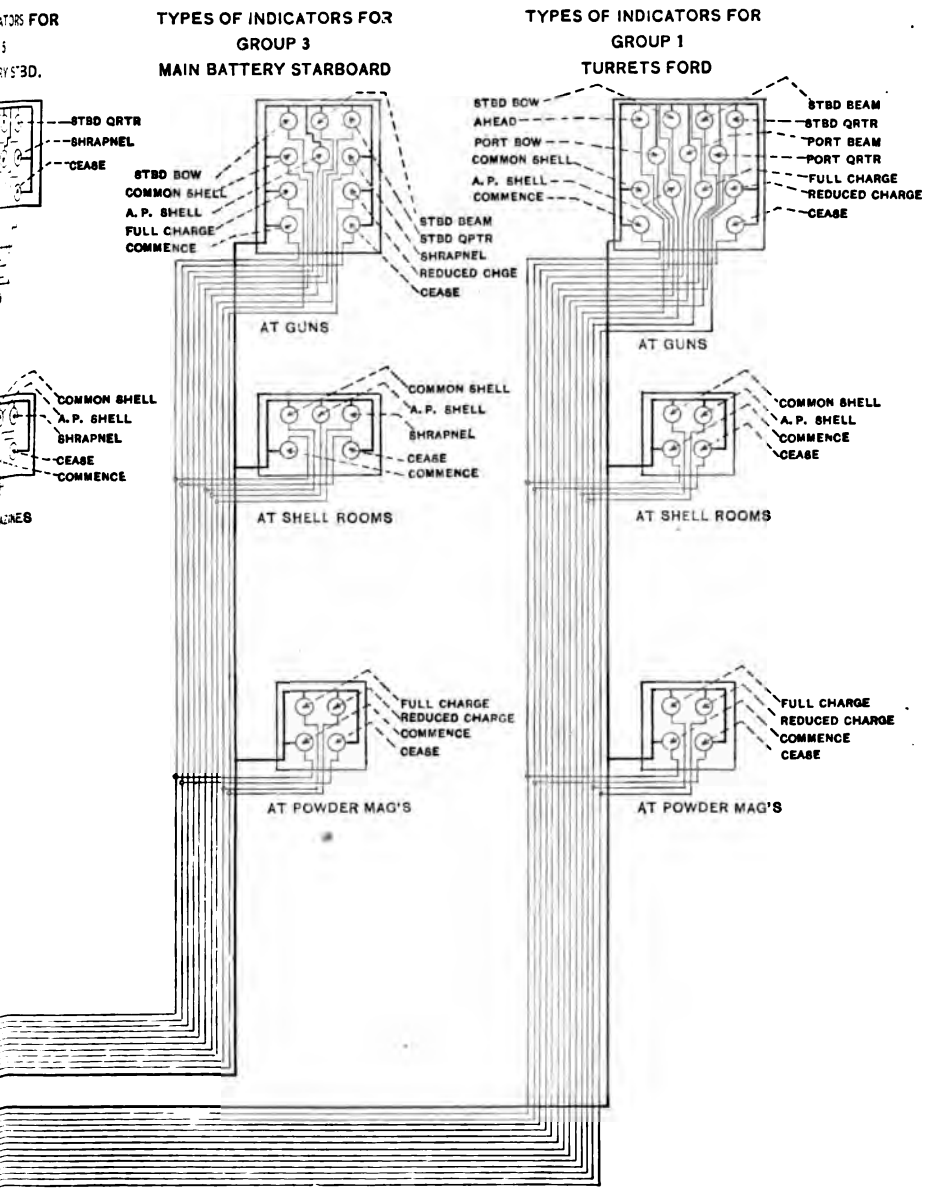


DIAGRAM OF ELECTRIC CONNECTIONS



FOR RANGE AND BATTLE-ORDER TRANSMISSION.

one hoist was originally fitted by which the single car was hoisted to a crane in the turret and then swung over to the loading-position. It was found that ammunition could not be supplied with sufficient rapidity and the system was unsatisfactory for other reasons as well. Because of the restricted size of the turret and ammunition-tube it was not possible to substitute two independent hoists; but the arrangement finally adopted has resulted in a much higher rate of fire than the original design permitted.

36. The tracks for the ammunition-cars lead to the center of the turret and at a half-way point, between the turret and handling-room, the tracks spread sufficiently to allow the two cars to pass each other, one car (loaded) coming up while the other (empty) passes it going down, both being operated by the same wire rope and a single electric motor. The car being at rest, the projectile is pushed out of the shell compartment on top of a *table A* (see Plate VIII), and brings up by the base against a stop at the rear end of the table. The projectile, *M*, is then rolled into *side rests, N*, on the top of *plates, B*, which pivot at the lower end, *C*, to the turret-floor, and which are allowed to swing off from the table, a distance controlled by the *chain, g*, bringing the projectile opposite the bore of the gun, *E*. The projectile is then shoved home by the rammer. The powder-charges are removed from the car by hand and passed to the loader who places them in the chamber.

37. By this arrangement, with a projectile in each of the pair of guns, three on the table and side rests, and one in the loaded car, six projectiles are ready for use. Overhead cranes are done away with and the supply of ammunition is much more rapid and more easily handled.

Communications for Battery Control.

38. The electric system of communications which has been supplied to many U. S. naval ships is shown in Plate IX.* The

* For the fire-control of a large battery, with the necessary range and deflection indicator for each sight-setter, this system calls for an expensive and heavy outfit of indicators and wiring. For this reason it is probable that it will be simplified in the near future.

order indicators which are installed at the guns, and at their principal ammunition supply-stations, are brass boxes with round pieces of ground-glass set in their fronts. The orders are printed on these glasses in heavy black letters, and in a pocket behind each is an incandescent lamp of low candle-power, the glow of which, when lighted, shows through and thus indicates the order transmitted. This shows clearly in darkness, and, while of course the orders on all the glasses, lighted or not, can be plainly read in daylight, those which *are* lighted are the plainer and mistakes in reading cannot occur. Each lamp has an individual leading-wire and a *common return* (see heavy line) running to the *transmitter* in the conning-tower; the leads of each indicator are enclosed in an ordinary pipe-conduit. The current is taken from the dynamo at the voltage of the ship's lighting-circuit.

39. The transmitter, in the conning-tower, is a regular switch-board with the standard orders written down its middle. Its switches are arranged so that an order impossible of execution cannot be transmitted; thus the two upper orders may be transmitted to every indicator, but the guns cannot be ordered trained on bearings *not in their arcs of fire;* similarly, shrapnel can be ordered only for those guns for which they are provided. The several indicators, moreover, will only show such orders as apply to the stations they are installed in.

40. The indicator of each supply-station is connected in parallel with the indicators of those guns which receive their ammunition from that station. Such indicators show only the orders to commence and cease firing and the kind of ammunition to be sent up. In many cases, provision is made for transmitting orders to the magazines and shell-rooms directly from the batteries to which they belong; this will prove useful in the case of a breakdown in the connection to the conning-tower. Everything about the system is as positive in its action as an electric device can be. Orders may be transmitted as long as current can be fed to the lamps; the latter are sensitive only in the same degree as ordinary ship's lamps.

CHAPTER XXXI.

ARMOR PROTECTION FOR SHIPS AND GUNS.

By Lieutenant-Commander Cleland Davis, U. S. Navy.

Historical.

1. In so far as it is of record, John Stevens, of Hoboken, New Jersey, was the first to propose the use of armor for the protection of vessels of war. In 1812, he designed a vessel whose battery was protected by inclined armor. This plan, however, like nearly all innovations, was not seriously considered. The Stevens family then began a series of investigations and experiments with armor that extended over many years, and in 1842, Robert L. Stevens submitted a report to a committee of Congress containing the results of these experiments, being deductions concerning the laws of the resistance of armor and the penetration of projectiles. These results were of great value to naval architects, and the principles therein set forth are to this day, many of them, applied in naval construction.

2. In 1854, Congress appropriated money for an ironclad on the Stevens design, and construction was begun, but the vessel was never finished. The development of the gun, however, in energy, range, and accuracy, and the introduction of explosive shell rendered the use of armor imperative, and thus we see the construction in 1855 immediately after the laying of the keel of the Stevens Battery, first by France and then by England, of armored batteries and ironclad vessels. This marks the adoption, generally, of wrought-iron armor. The United States quickly followed, and produced on the one hand by the Confederates the so-called ironclad, such as the Merrimac and on the other the novel type of turret vessel, the Monitor.

3. Further improvements in ordnance, especially the adoption

of the rifled gun, made it apparent that wrought-iron armor applied to vessels of war was of little avail against improved projectiles fired from rifled guns, so that strenuous efforts were made to increase the resisting power of armor, with the result that *compound armor* was developed in England, and *all steel armor* in France, early in the eighties. The efficiency of these two types was adout equal. The former had greater resisting power, but the tendency of the steel face to flake off over considerable areas made it unsatisfactory. However, the two about held their own until 1889 when the introduction of nickel into steel materially increased its toughness and power of resistance, so that homogeneous nickel-steel plates showed marked superiority over the compound type. Almost immediately thereafter, in 1890, the Harvey process was developed in the United States. The success of this process marked the greatest advance in the history of armor, and it was soon adopted by all the naval powers. The Krupp process, which followed in 1895, effected an improvement over Harvey, though the principle remained the same.

4. Experiments.—During all this time numerous experiments were made in the effort to produce novel types that would effect a saving in weight and cost of armor. Target structures of almost every conceivable description were made and subjected to ballistic test. There were homogeneous cast-iron and wrought-iron plates, and built-up targets of every description, including sheets of metal bolted together and presented flat or edgewise; alternating layers of metal and wood; of metal and rubber disposed in various ways, and of springs behind solid plates and between the laminations of built-up plates. The targets were fired at vertically, and inclined at various angles.

5. These experiments demonstrated the following general principles:

(1) That, to be efficient, armor must be homogeneous as to mass, so as to concentrate the resistance.

(2) That armor should be rigidly attached to the structure, and that devices such as springs or rubber cushions do not add to its resisting qualities, but are in reality a source of weakness.

(3) That inclined armor, designed to deflect the projectile upon impact, is about equal for purposes of protection, when the

angle of inclination is greater than the biting angle of the projectile, to vertical armor of equal weight; but when the angle of inclination is not greater than the biting angle, vertical armor of equal weight is more efficient. The introduction of the cap has not altered this principle.

Resistance of Face-hardened Armor.

6. Modern hard-faced supercarbonized armor is the logical development of the principles of compound armor. With the advent of the armor-piercing projectile it was recognized that to be defeated the projectile must be made to expend its energy upon itself. In other words, the resistance must be so concentrated as to greatly reduce the velocity of the projectile in a short space. The ideal armor-plate, therefore, would be composed of metal homogeneously hardened so as to make it as hard, if not harder, than the projectile itself, and at the same time so tough as not to be shattered upon impact of the projectile.

7. Compound armor.—But this was then, as it is now, metallurgically impossible of attainment, in the state of the art. The nearest approach to this principle was found in compound armor, which consisted essentially of a high-carbon-steel face and a wrought-iron back, the idea being for the hard steel face to break up the projectile and the tough back to hold the plate together. It was manufactured by casting the steel upon wrought-iron, the latter being heated and otherwise prepared to make as intimate a union as possible. This was a distinct advance upon the homogeneous wrought-iron armor, and compound armor was immediately adopted by nearly all the leading powers. The limitations of manufacture, however, made it practically impossible to obtain an intimate union between the two metals and so prevent flaking off of the steel plates, and caused the compound type to be superseded by homogeneous steel and homogeneous nickel-steel plates in the latter part of the 80's. Advance in the art of manufacture of steel enabled the manufacturers to produce steel of what was then considered a very superior quality.

8. Harvey armor.—The application by Mr. Harvey of the well-known process of *cementation* to homogeneous steel plates quickly

followed, and the result was the perfection of the compound armor principle, producing: *An integral plate supercarbonized to a considerable depth, giving an extremely hard, elastic face, bound together and supported by a tough back, having a minimum tendency to crack.*

9. The theory of resistance is as follows: When the point of the projectile strikes the face of the plate, the hard inextensible surface does not immediately give way, but there occurs an elastic or diaphragmatic dishing, in diameter equal to about three times the caliber of the projectile. The stress of impact is thus distributed over a considerable area, and the concentrated resistance works to suddenly stop the projectile and causes it to break up through its own inertia.

10. Krupp armor.—Krupp armor has exactly the same ballistic characteristics as that produced by the Harvey process. Its superiority is due to its composition, which makes it susceptible to treatment that improves the ballistic qualities. For example, Krupp armor has a greater affinity for carbon than the manganese nickel-steel used in the Harvey process, so that although the cementation may be accomplished in exactly the same way, carbon will be absorbed to a greater depth in Krupp than in Harvey plates, giving a greater depth of hard face in the former and thus increasing its resisting powers accordingly. Another point of superiority is a less tendency to crack in Krupp plates.

11. In both the Krupp and Harvey processes it is impossible to regulate the depth to which carbon is introduced or to increase that depth beyond a certain point. The reason of this is that the carbon is absorbed decrementally—that is, it begins to shade away from the surface, the carbon in each successive layer being absorbed from that immediately preceding it and being less in proportion so that the limit in the surface layer being fixed to retain the characteristics of steel, the depth to which carbon is introduced is determined by that limit.

12. Theory of the cap.—The introduction of the cap which is now fitted to all armor-piercing projectiles materially reduced the resisting power of hard-faced armor. For so simple a device, its effect is marvelous. At normal impact and up to an angle of nearly 30 degrees the cap increases the penetrating power of the

projectile about 15 per-cent, with respect to velocity, and over 20 per-cent with respect to thickness of the plate; but it has another very important advantage in that it decreases the tendency of the shell to break up, preserving it so that it is well conditioned for bursting after passing through. It is efficient only against hard-faced armor, and it is a question whether its action has been satisfactorily explained. The most plausible theory is as follows: When the mass, consisting of projectile and cap, meets the hard face of the plate, the latter is elastically dished and the resistance concentrated. The cap is strong enough to transmit the stress of impact, and at the same time the projectile proper is not stopped suddenly as is the case with an uncapped projectile; it continues to advance through the cap, its passage through the latter being comparatively easy, and when the point reaches the plate it finds the latter already dished, perhaps, to its elastic limit. The resistance then becomes purely local, and the effect is similar to the impact of an uncapped projectile against homogeneous plate, save the flow of displaced metal to the front, which occurs in the latter.

13. Future development of armor.—It is, of course, impossible to predict with any certainty the course of development of armor. It is probable, however, that it will be along the lines of improvement in the quality of steel and methods of manufacture, following the face-hardened principle, rather than any radical change in type or mechanical construction. Recent improvements in the quality of projectiles, assisted by the cap, are such that the hard face of armor, as now manufactured, is not equal to the task of stopping the projectile; so that improvement in the quality of the metal of the hard face, as well as greater depth, would seem to be demanded.

MANUFACTURE OF ARMOR.

14. The manufacture of modern face-hardened armor comprises a series of operations which require the greatest care and attention to details to produce the best results, and these operations are so elaborate that a period of nine months is allowed in the manufacture of service armor from the time of the receipt of

the original drawings until the completion and delivery of the plates. The ingot is cast from steel made by the open-hearth process. The composition is predetermined, and for service Krupp armor consists in general of mild low-carbon steel, containing inseparable ingredients of phosphorus, sulphur, and silicon (the percentage of which it is endeavored to keep at a minimum), and nickel, chrome, and manganese. The two former (nickel and chrome) predominate and give to the steel those qualities that make it efficient for armor. The nickel, and to a certain extent the manganese, gives great strength and toughness to the metal, while the chrome makes it susceptible to treatment that gives the desired qualities to the finished plate. First, it permits the attainment of a very tough fibrous condition throughout the body of the plate that makes it less liable to crack; second, it gives the metal an affinity for carbon which enables supercarbonization to a greater depth; third, it increases the susceptibility of the metal to tempering, which gives a greater depth of chill. It is these qualities which mark the superiority of Krupp armor.

15. The various operations through which the finished plate must pass during the manufacture are as follows:

(1) Casting of the low-carbon ingot.
(2) Stripping the ingot.
(3) Forging.
(4) Removing the scale and chipping out forged defects in the surface.
(5) Rough-machining.
(6) Carbonizing.
(7) Scaling.
(8) Re-forging.
(9) Annealing.
(10) Machining.
(11) Bending.
(12) Tempering.
(13) Rectifying.
(14) Finish-machining and erecting.

16. Tests.—In addition, specimens for physical tests are taken after forging and after tempering. Borings are taken from the surface after carbonizing to determine the depth of carbonization.

17. The above operations are practically identical with both the Krupp and Harvey processes, the main points of difference being in the "treatment" of the former. By "treatment" is meant the manner of heating and cooling and its object is to relieve internal strains and produce a tough fibrous condition of the metal.

18. Casting the ingot.—The ingot mould is made up of cast iron sections, the parts of which are bolted together, the hori-

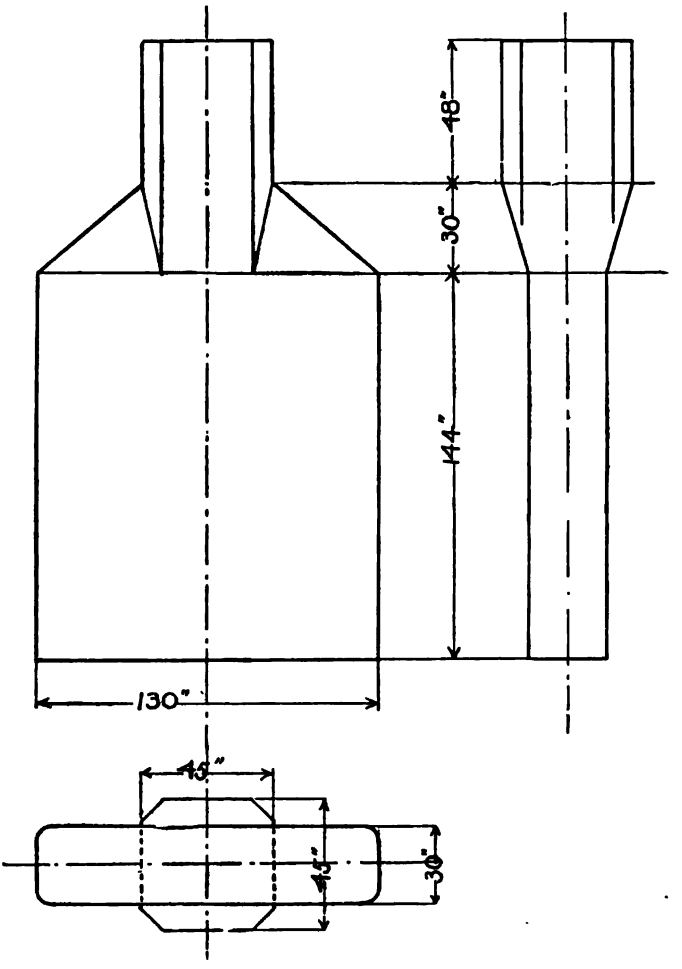


FIG. 1. ARMOR INGOT. ART. 19.

zontal sections being held together by clamps. Each section contains on the interior numerous vertical webs, between which the back sand is pressed. A wooden pattern, in sections, is used,

around which the facing sand (that next the ingot) is tightly pressed by rammers. The pattern is finally withdrawn, and long nails driven into the sand at close intervals to hold together the facing and the back sand, thus making the mould stronger, permitting the ingot to strip better. Outside of, and at each end of the mould, is a vertical tube or gate, each connecting with the interior of the mould at the bottom, near the middle of its length.

19. *The molten metal* is run from the open-hearth furnace into a large ladle, which in turn is moved over a gate of the mould and then tapped. It is to get rid of the part containing segregation that the discard is made. When the mould has been filled, it is allowed to cool. The shape of the ingot is shown in the accompanying sketch. The projection on one end is for the purpose of handling the ingot.

20. Stripping the ingot is done as soon as it has cooled sufficiently; the mould is removed and the ingot cleaned of the facing sand.

21. Forging.—The ingot is then heated and taken to the forging press where it is forged to a thickness about one-third greater than that of the finished plate; the sink-head is then cut off and the forging assumes the appearance of a finished armor-plate. The following is a description of the Bethlehem Steel Company's 14,000-ton forging press (see Plate I).

The Forging Press.

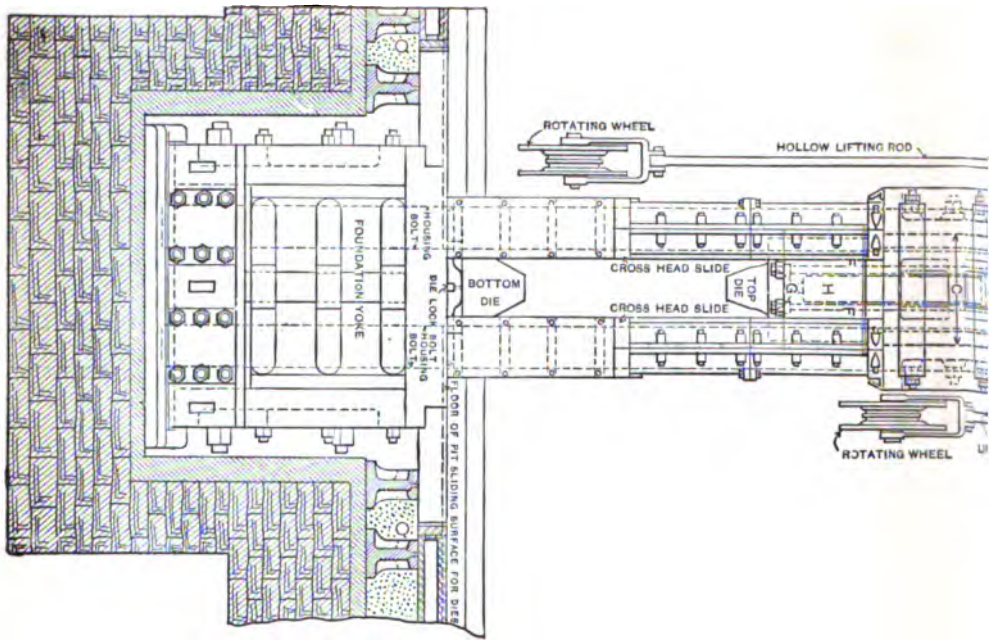
22. (1) **The construction of the press** embodies a number of principal parts which are named or lettered on the plate mentioned.

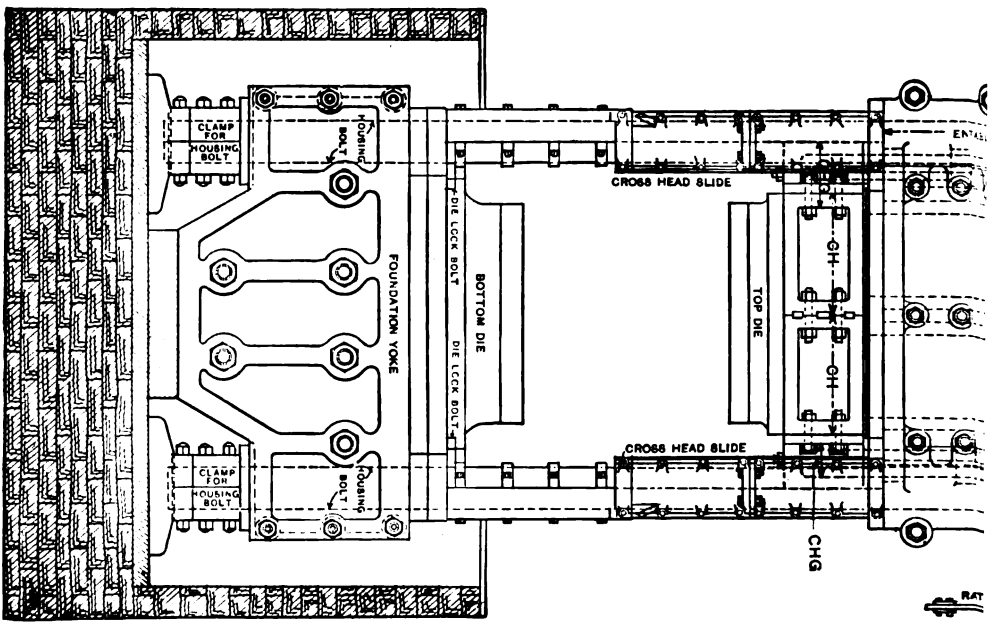
(2) The *foundation yoke* is made of heavy sections bolted together by powerful bolts.

(3) Four vertical *housing bolts* pass through the "foundation yoke" and through the *entablature,* which is made in two parts clamped together by heavy bolts.

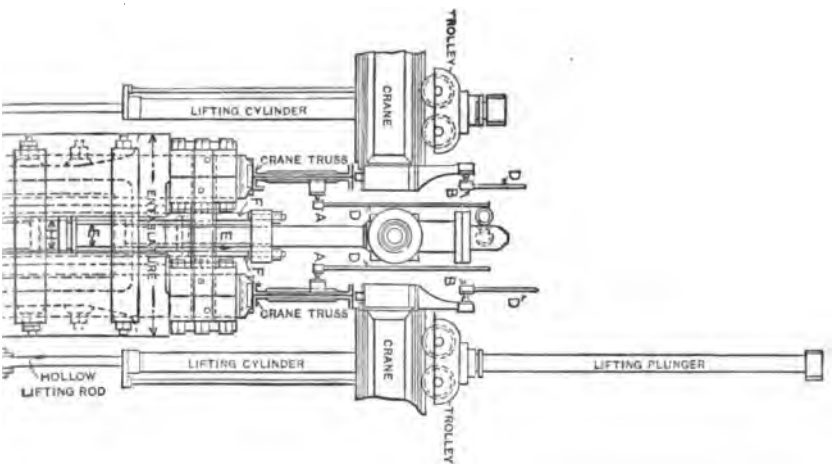
(4) A number of parallel grooves, somewhat similar to threads, are cut at each end of each housing bolt and *split clamps* are bolted over these threaded parts, thus transmitting all strain due to forging, through the housing bolts, and making of the entablature, the foundation yolk and the four housing bolts, a self-contained apparatus requiring no bracing from without.

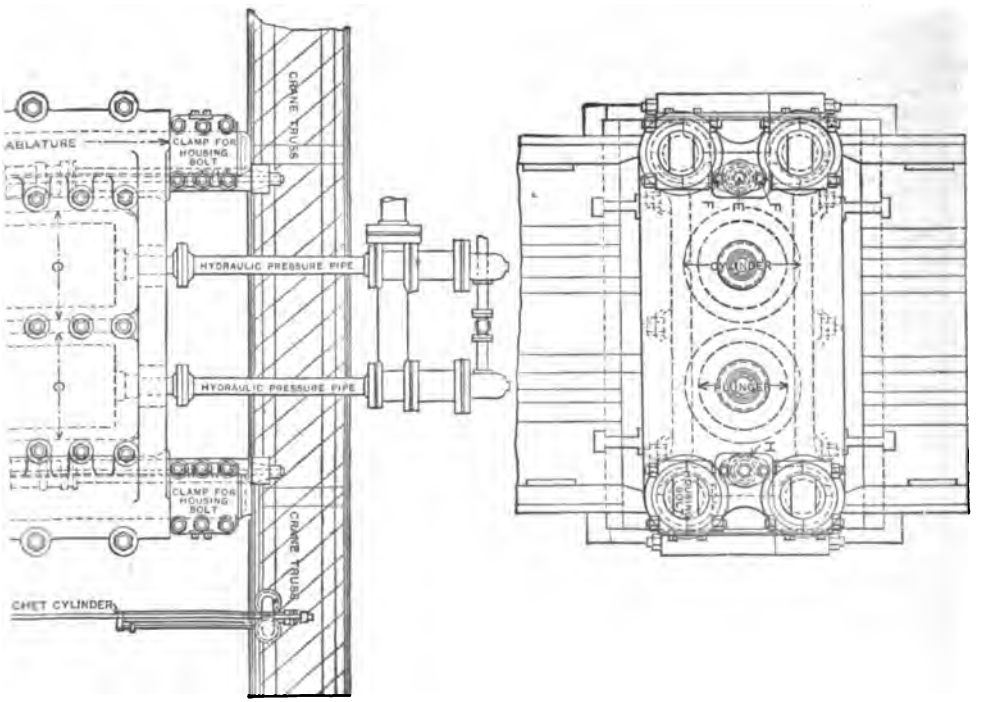
(5) The entablature is bored out to receive two steel cylinders (marked "C" "C") of 50½ inches internal diameter.





THE BETHLEH
50½-INCH DOUBLE





:M STEEL CO.
FORGING PRESS.

(6) Within these two cylinders, two *plungers* operate with vertical motion.

(7) Cast on the bottom end of each of these plungers and in one piece, with each plunger, are the two halves of the *cross-head* (marked "C. H.").

(8) Bolted to each end of the cross-head are the *cross-head guides* (marked "CHG") which serve to transmit lateral strain to the *cross-head slides*, which are bolted to each of the four vertical housing bolts.

(9) A removable *bottom die* is arranged to slide on the steel floor of the pit. This die is made either straight or tapered along its top edge according to the shape of the armor plate desired.

(10) This die is pushed along the floor of the pit in either direction by an apparatus operated by two powerful hydraulic cylinders, which are not shown on the drawing.

(11) The removable *top die* may be bolted to the under surface of the cross-head, and this die also may be made of the proper shape to forge any shape desired in the armor-plate. Hydraulic pressure is introduced to the interior of the cylinders by *hydraulic pressure pipes* passing through the top of the entablature and fitted into the tops of the cylinders in such a manner that the greater the pressure, the tighter the joint becomes. The engine for producing this pressure is not shown in the drawing, but is capable of producing a pressure of seven thousand pounds per square inch.

(12) The total maximum pressure which the press is able to exert, is in the neighborhood of fourteen thousand (14,000) tons.

(13) The seven thousand (7000) pounds hydraulic pressure is used only for driving the plungers downward, as the forging is done on the down stroke. The plungers are lifted on the stroke after each blow, by two *lifting cylinders*, one on each side of the press (marked "H").

(14) A plunger (marked "E") operates in each cylinder ("H") which is connected to the cross-head through two lifting rods (marked "F" "F"), which pass through the cross-head guide on each side and are secured by nuts shown at "G."

(15) In order to remove dies from the pit, to place new dies in the pit, and to handle armor-plate ingots which are being forged, two heavy traveling cranes are used with a capacity of about 250 tons each. These cranes are also used to charge ingots into the heating furnaces and to draw them from the furnaces when they are ready to be forged.

(16) The ingots are carried in a very heavy flat link-chain, similar to a bicycle-chain on a large scale.

(17) This chain passes over a *rotating wheel*, to which rotary motion can be imparted by means of a combination of worm- and spur-gearing not shown on the drawing.

(18) The worm is situated at the bottom end of a vertical shaft which passes through the *hollow lifting-rod*. On the top end of the vertical shaft are arranged bevel gears which are connected through a series of shafting to a pneumatic engine situated at one end of the crane.

(19) The hollow lifting-rod is fastened at its top end to a small cross-head extending across the tops of two *lifting-plungers.*

(20) These lifting-plungers operate up and down in a pair of lifting-cylinders which are carried along the bridge of the crane by a heavy *trolley.*

(21) The motion of the trolley along the bridge of the crane is obtained by means of a pair of pneumatic engines situated at one end of the crane.

(22) The bridge of the crane is also moved along the rails on the top of the crane trusses by a pair of pneumatic engines.

(23) All the pneumatic engines on the crane are controlled by an operator in a cage at one end of the crane.

(24) All lifting on the crane is done by hydraulic power under a pressure of twenty-six hundred (2600 lbs.) pounds to the square inch.

(25) The hydraulic power, as well as the pneumatic power, is transmitted from stationary connections (marked "A" "A") through hinged *scissors pipes* (marked "DD") to the moving connections (marked "B" "B") on the plate. Separate pipes are used for the water and air, although only one set of pipe connection is shown.

(26) The lifting-rods on the crane are controlled by a lever situated on the floor of the building.

23. The process of forging.—The armor ingot being heated to a red heat is removed from the furnace by the crane, the chain being secured at the projection on the ingot, and the weight of the ingot being counterbalanced by a long, heavy beam on the opposite side of the lifting chain.

24. The ingot is swung easily into position and its end is pointed fair and landed on the lower die of the forging press (see Plate I). The upper die is then forced down upon the ingot, the throw being so regulated as to diminish the thickness of the ingot about 3 inches at each stroke. The metal flows evenly in all directions under the irresistible and steady pressure of the press, and after each stroke the ingot is moved along on the lower die until its thickness has been reduced by the same amount throughout its length. Its thickness is thus gradually diminished, while its length and breadth are increased until the desired dimensions are reached.

25. The removal of scale, etc.—The surface to be carbonized is then carefully scaled and any forging defects, such as "laps," are chipped out.

26. Rough-machining.—The plate is next machined to the approximate dimensions of the finished armor-plate.

27. Carbonizing.—After forging, the surface of the plate is carbonized, or carburized, as it is sometimes called; the word *supercarbonized* is also used. This is an adaptation of the long-known process of *cementation,* which means heating the metal to a high temperature in the presence of carbon and maintaining that heat for a considerable time; carbon will be gradually absorbed into the surface.

28. Two methods are employed—the dry-carbon cementation proper, and the gas-carbonizing process; the latter was formerly one of the distinctive features of the Krupp process. But it is now well known that the dry-carbon method, essentially the Harvey process, gives at least as good results as the gas method, and one of the great armor firms of the country employs the dry-carbon method in the manufacture of Krupp armor.

29. The dry-carbon furnace is built with a row of longitudinal flues under its floor. The flame from the coal comes from two fires placed at the smoke-stack end of the furnace, passes over the charge, then down vertical flues in the opposite end and then returning to stack through the longitudinal flues underneath the floor.

30. In this furnace two plates are generally carbonized together, the bottom plate resting on a bed of sand. The dry carbonizing material is placed on top of this plate and the other plate placed face down on the carbonizing material. The whole charge is then covered with sand to prevent contact with the flame or with air.

31. *Two gas-pipes* are run through the carbonizing material into which iron rods are introduced and periodically drawn to examine the temperature of the furnace; the temperature being judged by the color to which these rods are heated.

32. *The carbonizing material* is a mixture of wood and animal charcoal. The time necessary for carbonization varies as with the gas furnace, according to the thickness of the plate. It takes generally from four to ten days to bring a furnace up to heat, after which it is maintained from four to ten days at the heat of carbonization, which is about 1950° F. The charge is then cooled slowly and the plates removed after they have cooled down below a red heat.

33. The gas-carbon furnace is so arranged that the gas-flame is supplied through a row of ports on each side, only one side being used at a time, that is, one side is used for a short time, when the flame is shut off from that side and the ports on the other side opened, the flame in each case being deflected from the ceiling of the furnace. During carbonization, temperatures are taken with a Siemens pyrometer, the temperature balls being placed on top of the upper plate. The time necessary for carbonization varies with the thickness of the plate; it takes about two days to bring the furnace up to heat, after which five to thirteen days are needed.

34. The plate having been introduced, the furnace is brought to a temperature of approximately 2000° F., and coal gas is passed along the face of the place which is to be carbonized. The heat breaks up the gas and deposits carbon on the face of the plate, and this carbon is gradually absorbed until the desired degree of carbonization is obtained. From the time of charging until the operation is completed requires a little over three weeks.

35. Depth of carbonization.—Even when cementation is accomplished in the same manner, carbon will be absorbed to a greater depth in Krupp than in Harvey armor, giving a greater depth of chill or hard face, and an increased resistance to penetration of about 25 per-cent.

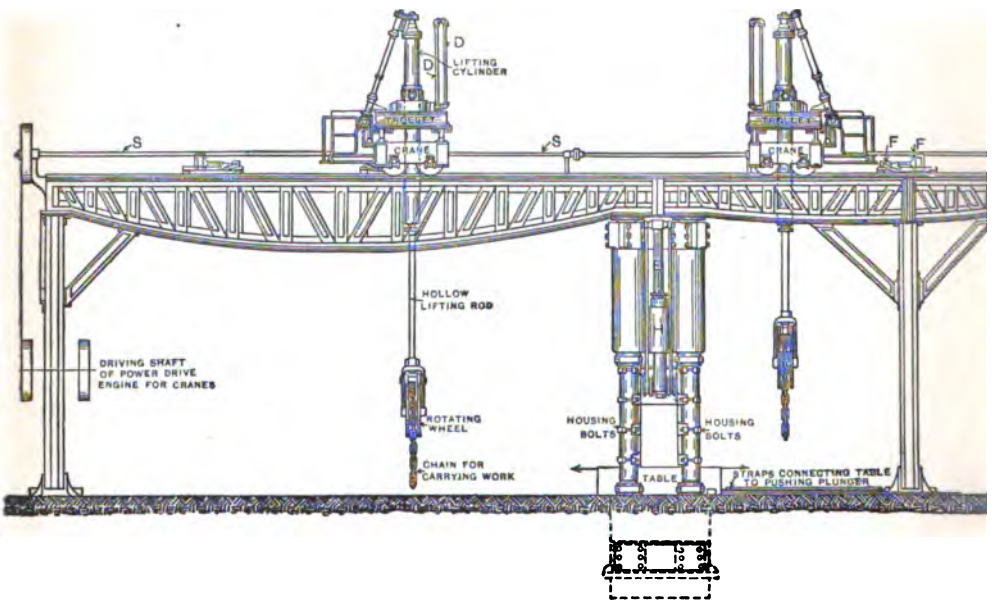
36. The normal carbon content being, say .23, a typical analysis of a carbonized face would be—on surface, 1.2 per-cent of carbon; at ¼ inch, .90 per-cent; at ½ inch, .60 per-cent; at ¾ inch .35 per-cent; and at one inch, normal or .23 per-cent.

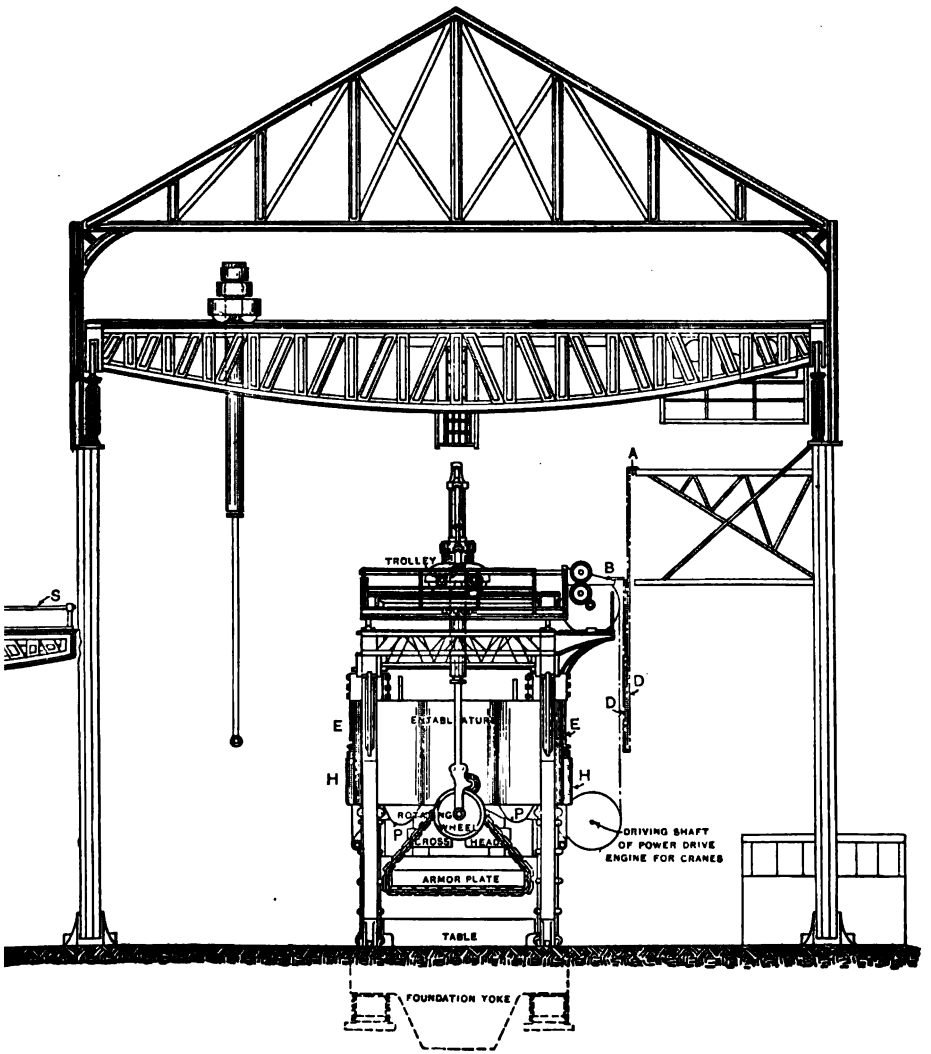
37. Scaling.—After carbonizing, the face is carefully scaled and cleaned, the scaling being done by hand with pneumatic chisels.

38. Re-forging.—The plate is then reheated and forged to its final thickness. The object of this re-forging is to counteract the effects of the long-sustained heat, or soaking, to which the plate was subjected in the carbonizing furnace.

39. Annealing.—While "treatment" is at all times important, it is most so after re-forging, for it is at this point that annealing or "treatment" gives to the body of the plate that tough fibrous condition that is a characteristic of Krupp armor.

THE BETHLEHEM STEEL CO.
7000-TON HYDRAULIC BENDING PRESS FOR ARMOR PLATE.
GENERAL ARRANGEMENT.




A
B
S
TROLLEY
D
D
E
E
H
H
P
P
ENTABLATURE
ROTATING CHEEL
CROSS HEAD
DRIVING SHAFT OF POWER DRIVE ENGINE FOR CRANES
ARMOR PLATE
TABLE
FOUNDATION YOKE

40. Machining.—The plate is next machined as much as possible before bending.

41. Bending, in which rather greater care is necessary with Krupp than with Harvey plates, is next accomplished with the bending press described below. The plate is landed on the table where it is given the required curvature by men who, by long experience, are especially skilled in this operation.

Bethlehem Steel Co.'s 7000-ton Hydraulic Bending Press.

42. (1) The bending press shown in Plate II is, in general, similar to the forging press, having a *foundation yoke* and *entablature* connected by four housing bolts and having two plungers operating a cross-head and sliding in two vertical cylinders contained in the entablature.

(2) A *sliding table* is, however, arranged on the floor of the press in place of removable dies, as in the forging press.

(3) The two plungers P. P. have rounded ends on the bottom, forming with the rounded cavities on the cross-head a pair of ball-and-socket joints which allow the cross-head to be inclined to a horizontal when necessary, to produce a twist or wrap in the armor-plate.

(4) The cranes are operated by a steam engine bolted to one of the columns supporting the crane trusses. This engine is connected to a long shaft (marked "S") by means of a belt fastened over two belt pulleys.

(5) The cranes are similar to those at the forging press and the *scissors pipe* hydraulic connections are shown at "D" "D" being connected with the stationary pipe at "A" and with the moving pipe at "B."

(6) The long shaft ("S") is supported at the extreme ends and at its center by stationary bearings; intermediate between these bearings are arranged special *tumbler bearings* (shown at "F" "F") so arranged that when the crane is about to occupy the space where one side of the bearing supports the shaft, this side of the bearing is made to fall out of the way, and by falling to elevate the other side of the bearing into position to support the shaft.

43. Tempering.—The plate is next heated to the required temperature and sprayed with cold water, at a pressure of about 23 pounds to the square inch, from a specially designed apparatus. The plate usually warps and becomes distorted under the treatment and great skill is exercised in regulating the spray and giving the plate "reverse curvature" so as to anticipate the distortion; that is, the plate is bent before tempering to a smaller radius of curvature than designed for the finished plate.

44. Rectifying.—With even the most skilled workmanship, the plates often have to be rectified; this is done under the bending press, sufficient allowance always being made in bending for the distortion in tempering, so that, in rectifying, the carburized face will be compressed; otherwise, dangerous cracks will appear in the hard face. The temperature for the purpose must not be more than 100 degrees less than that of the last annealing.

45. *Such cracks as might develop* while rectifying are dangerous and seriously affect the ballistic qualities of the plate. They must not be confounded with the characteristic cracks that appear in the surface of finished Krupp armor-plates. When Krupp armor was first manufactured in this country, the characteristic cracks were always present and usually very marked, sometimes ¼ inch wide, and were considered indicative of normal plates. As the armor-makers gained experience, however, they were able to produce smoother plates, until now, in normal plates, the surface is usually continuous to the naked eye. But if the surface be etched and polished, the whole face would present the appearance of a net-work of minute lines, much like the lines in a plate of glass that has been heated and suddenly plunged into cold water.

46. Finish-machining and erecting.—The plates are now carefully machined and fitted together so as to make continuous joints. Armor structures, such as turrets and barbettes, are erected complete at the armor-makers, as are sections of the side and casemate-armor; all being set up in exactly the same position or form the armor occupies when attached to the ship, measurements being taken from a datum plane which fixes the position of the armor on the ship itself.

47. *Non-cemented armor.*—Plain nickel-steel and Krupp non-cemented steel, which is produced in the same manner as described, omitting the operations of carburizing and re-forging, is used for special purposes such as protective-decks, splinter-bulkheads, armored tubes, doors, etc.

48. Method of securing armor to the ship.—Wood backing is used for the purpose of insuring a good fit and to provide a sufficient length of armor-bolt. It is being gradually reduced in thickness, and the tendency is to discard it altogether. In battle-

ships of the Virginia class, and in subsequent designs, it has been given up for barbettes. It is not used for conning-tower armor, signal-tower, interior armor, or gun-positions outside the casemate, except turrets. The 4-inch side- and casemate-armor of the St. Louis class is being fitted without backing, the plates being disposed vertically, 8 feet wide and about 17 feet long, extending from the armor-shelf to the port-sill.

49. Armor bolts.—The following table shows the size of bolt for each thickness of armor:

Size of bolt.	Thickness of armor.
1.5 inches	To and including 5 inches.
2.0 inches	From 5 inches to 9 inches.
2.4 inches	From 9 inches to 13 inches.

50. (1) Armor bolts are so spaced as to provide one bolt for every five square feet of surface, so far as the framing behind armor will permit, except in the case of 3-inch armor for which one bolt is used for about six square feet of surface.

(2) Plate III, Figs. 1 and 2, shows types of bolts for armor with and without wood backing.

(3) The bolts are made of nickel steel of such remarkable toughness that the plate will remain in place even if severely cracked.

51. Specifications for armor.—The following are extracts from circulars, specifications, etc., 1905, for the manufacture of armor:

52. The armor defined in these specifications shall, for the purpose of distinction, be classed as follows:

(1) *Class A, consisting* of armor-plates having a thickness greater than 5 inches, to be manufactured, re-forged, and face-hardened by the best and most improved process, to be satisfactory to the Bureau of Ordnance.

(2) *Class B,* consisting of armor-plates having a thickness of 5 inches or less, to be manufactured, re-forged, and face-hardened by a process satisfactory to the Bureau of Ordnance.

(3) *Class C,* consisting of thin plates and hollow forgings, such as turret tops, doors, communication and ammunition-hoist tubes, to be oil- or water-tempered and annealed, but not face-hardened. Class C armor is not subject to ballistic test.

(4) *Class D,* consisting of armor-bolts and nuts.

53. The ballistic test for acceptance of armor of Class A shall in no case be less severe than the following:

(1) There shall be three impacts with striking velocities as given in the following table, capped armor-piercing projectiles being used:

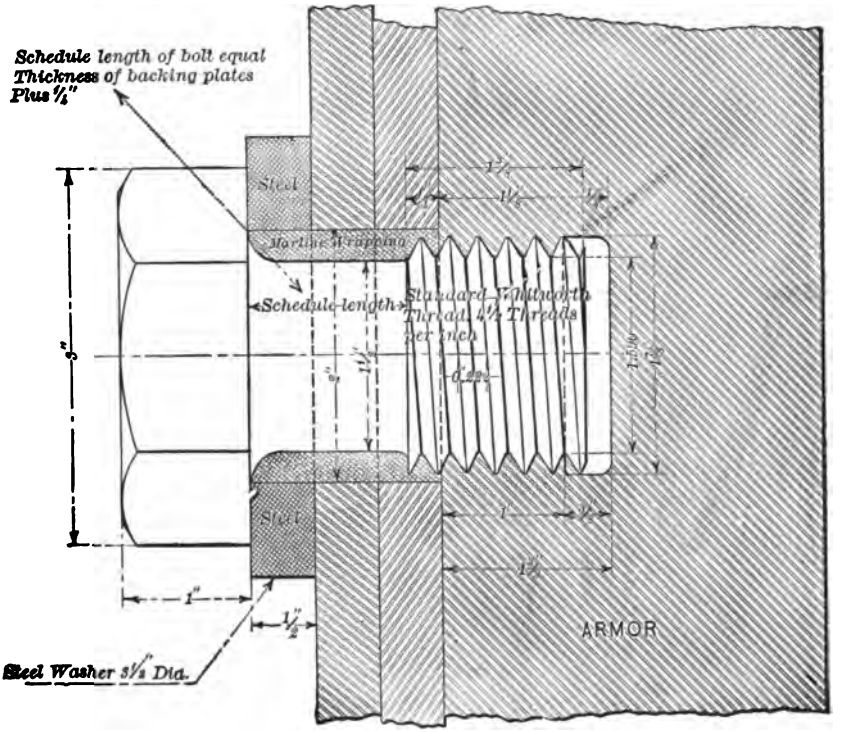


FIG. 1.

1.5-INCH BOLT FOR THIN ARMOR, WITHOUT BACKING.

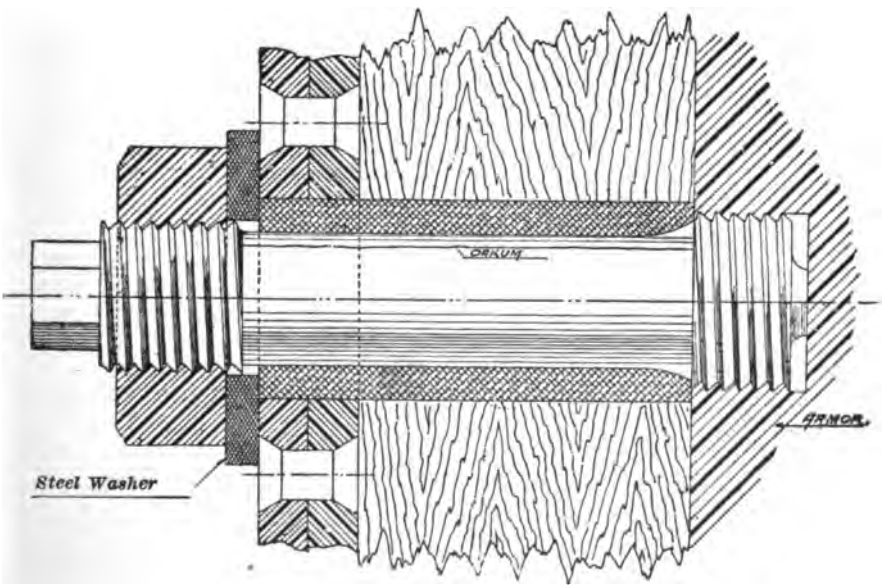
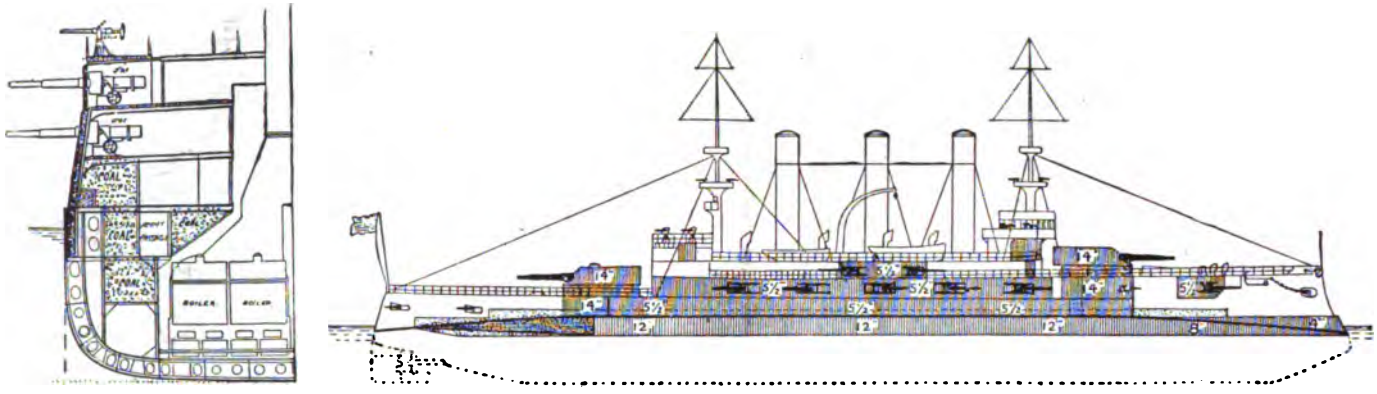


FIG. 2.

STANDARD ARMOR BOLT.



TYPE OF BATTLESHIPS SIMILAR TO THE MAINE CLASS.

Wt. of shell capped. *Pounds.*	Caliber of gun. *Inches.*	Thickness of plates. *Inches.*	Striking velocity. *Foot-seconds.*
105	6	5	1,416
105	6	6	1,608
105	6	7	1,791
165	7	6	1,416
165	7	7	1,578
165	7	8	1,732
260	8	7	1,412
260	8	8	1,552
260	8	9	1,685
510	10	9	1,458
510	10	10	1,569
510	10	11	1,676
870	12	11	1,412
870	12	12	1,501

(2) The first impact shall be located near the central portion of the plate, and on this impact no portion of the projectile shall get entirely through the plate and backing, nor shall any through-crack develop to an edge of the plate.

(3) There shall be two other impacts with capped armor-piercing shell to be located as may be directed by the Bureau; no impact, however, to be nearer another impact or an edge of the plate than 3½ calibers of the projectile used. On these impacts no shell or fragment thereof shall get entirely through the plate and backing.

(4) Excepting as to the striking velocities used, the ballistic tests for acceptance of armor of Class B shall in all respects conform to that detailed for armor of Class A.

(5) In the test of armor of Class B the striking velocities shall be as follows:

Wt. of shell capped. *Pounds.*	Caliber of gun. *Inches.*	Thickness of plate. *Inches.*	Striking velocity. *Foot-seconds.*
33	4	3.5	1,233
33	4	4	1,355
33	4	5	1,585
50	5	4	1,300
50	5	5	1,521

(6) The above tables are based on the De Marre formula for the perforation of homogeneous steel:

$$V = [3.00945]\frac{d^{0.75}\, e^{0.7}}{p^{0.5}}, \text{ in which}$$

V = the striking velocity in foot-seconds;
d = the caliber of the gun in inches;
e = the thickness of the plate in inches, and
p = the weight of the projectile in pounds.

(7) To the velocity thus found in any case, there shall be added 20 per-cent when a 6-inch gun is used, 18 per-cent when a 7-inch gun is used, 20 per-cent when an 8-inch gun is used, 23 per-cent when a 10-inch gun is used, and 18 per-cent when a 12-inch gun is used, and the velocity thus increased is to be the striking velocity used against armor of Class A.

(8) In the test of armor of Class B, the striking velocities shall be 2 per-centum greater than those determined by the De Marre formula for plates of even thickness.

(9) For plates having a thickness not shown in the tables, the striking velocity shall be determined by interpolation, the Bureau to decide whether the caliber of gun next greater or next smaller shall be used.

ARRANGEMENT AND DISTRIBUTION OF ARMOR ON U. S. SHIPS.

54. The arrangement of armor of various classes is as follows:

(1) *Plates above 5 inches in thickness* consist of cemented or supercarbonized steel plates, face-hardened by the Krupp process, comprising, on battleships, the main side-belt armor, turrets, barbettes, conning-tower, casemate, and intermediate-battery protection.

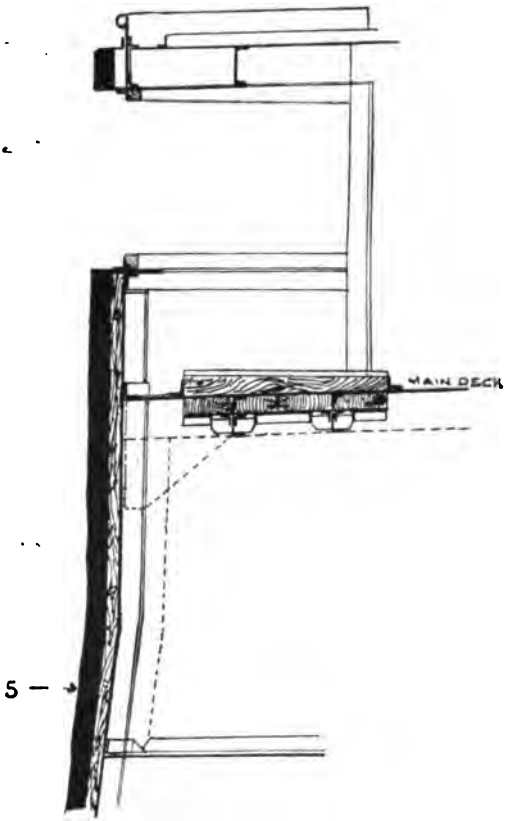
(2) *Plates not over 5 or less than 3 inches* in thickness consisting of steel plates, face-hardened by the Harvey process, comprising the side-armor plates forward and aft, when the thickness tapers to 5 inches or less, fore-and-aft and athwartship bulkheads, etc.

(3) *Thin plates,* such as splinter bulkheads, protective-decks, protection for minor-caliber guns, turret-tops, sighting-hoods, signal-towers, ammunition- and conning-tower tubes are made of homogeneous nickel steel.

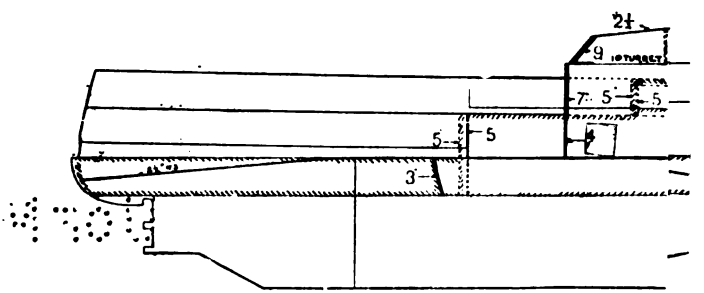
(4) *Small, thick pieces,* such as armor doors, strips above gun ports, etc., are made of Krupp non-cemented steel.

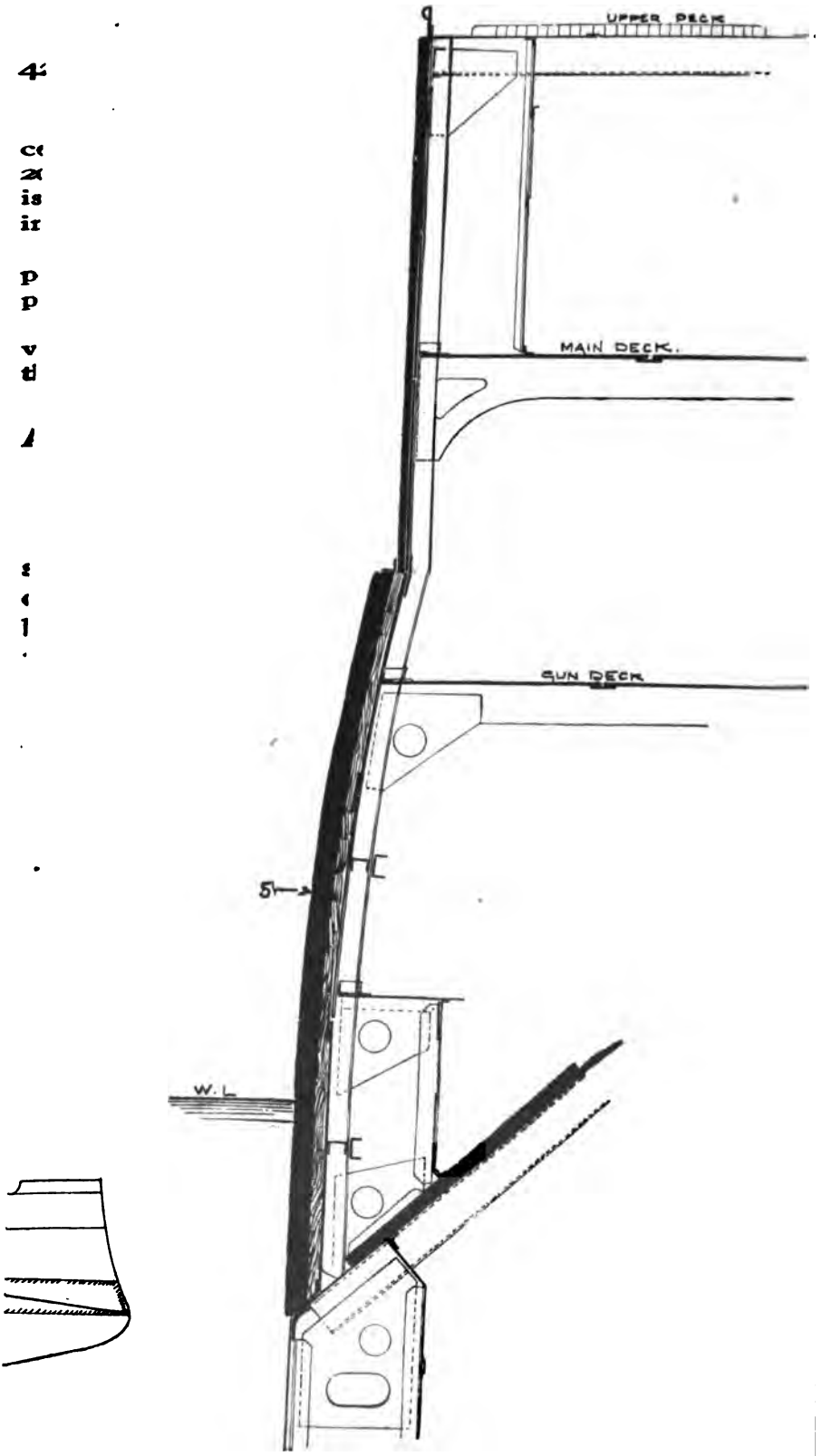
55. The thickness depends first upon the importance of the position it is designed to protect and next on the resisting power of the armor. For the purpose of design, it is assumed that Kruppized armor will keep out projectiles of caliber equal to its thickness at fighting ranges.

56. Protective- or armored-decks may properly be classed as armor and their function is so peculiar and important that it



SECTION THROUGH 6"·1 GUN PORT
—— MAIN DECK. ——




UPPER DECK
MAIN DECK.
GUN DECK
W.L

merits special attention. In all armored vessels, the value of protective-decks is recognized. In designs up to, and including, the Maine class, it was the practice to work a flat deck at the level of the top of the side-armor for the length of the machinery and boiler spaces, carrying it to the bow and stern with sloping sides, the angle being usually 45 degrees, and sloping to below the water-line at the bow and stern. In later designs, the slope is carried fore and aft, the angle of inclination remaining 45 degrees, touching the bottom of the armor-belt. In general, the thickness of the armored deck, both for battleships and armored cruisers, is from 2½ to 4 inches on the slopes and from 1 to 2 inches on the flat. Armored decks are very heavy, taking up a considerable proportion of the total weight of the armor. While the same weight applied to the side-armor would no doubt offer equal if not greater resistance to actual penetration, the fact that such decks will prevent fragments of shell that might perforate the side-armor, from reaching the vitals, coupled with the great structural strength it adds to the vessel, makes armored decks an essential if not indispensable feature of warship design. A splinter-deck, about one inch thick, is sometimes worked in as the deck next above the protective-deck.

Armored Battleships.

57. Oregon.—The evolution of design with reference to armor is brought out by a consideration of the types from the Oregon to the Connecticut class. The former has a very heavy water-line belt, 18 inches in thickness, extending along the machinery, magazine, and boiler spaces. At the ends of this are the barbettes, 17 inches thick, rising on the center line above the main deck. The ends of the ship are unarmored. The barbettes protect the turret turning-gear and ammunition supply. Mounted over the barbettes are the turrets for the 13-inch guns, with 15 inches of armor at the sides and back and 17-inch port plates. The casemate armor is 5 inches thick, but is of limited extent, and but poorly protects the two broadside 6-inch guns. The quadrilateral 8-inch turrets have 8½ inches of armor, the barbettes are 10 inches and the ammunition tubes 3 inches thick.

Part of the secondary battery is protected by 2-inch armor, and thin gun-shields. There is a conning-tower, 10 inches thick, and a 7-inch communication tube. These vessels were designed before the Harvey process had been adopted for armor, though most of the armor was treated by that process.

58. Iowa, Kearsarge, and Kentucky.—The Iowa followed, the armor being distributed on the same general lines, but thinner in corresponding positions. In the Kearsarge and Kentucky we find a slight decrease in thickness to 16 inches and an extension of the water-line belt to the bow, tapering in thickness to 4 inches. In place of the quadrilateral 8-inch turrets of the Iowa, 8-inch turrets were superposed on the 13-inch turrets. This arrangement provoked much criticism and its value is still a moot question. The barbette and turret-armor were slightly decreased in thickness and more importance given to the casemate-armor, 5 inches thick, which was made to cover all the space between the barbettes. The conning-tower, tubes, etc., remained practically the same.

59. Illinois class.—Next came the Illinois class, including the Alabama and Wisconsin. The principal features of the armor design of these vessels was the abandonment of the 8-inch turrets, a more extensive use of the casemate armor, which was made 5½ inches thick to protect the 6-inch battery, the introduction of splinter-bulkheads, and what is very important, the adoption of the inclined port-plate for the 13-inch turret-guns.

60. Maine class.—The Maine class followed. The general design of these vessels is similar to that of the Illinois; 6-inch armor was used for the casemates, and Krupp armor being at this time adopted, the armor protection was considered to be very much superior to the Illinois class. For a similar design, see Plate IV.

61. Virginia class.—In the Virginia class there is a return to the 8-inch turrets, two being superposed on the 12-inch like the Kearsarge and Kentucky and two being placed in broadside. However, the inclined port-plates of the former which permits of a minimum port opening, and at the same time are inclined at a sufficient angle to deflect projectiles, give very much better protection, though the thickness is only 6½ inches against 8 inches for the Kearsarge. The belt was made 11 inches, but

was carried all the way aft, tapering to 4 inches at the stern as well as at the bow. The casemate was still further extended, being carried forward and aft with athwartship bulkheads so as to include the 12-inch barbettes.

62. Connecticut and Louisiana.—In the Connecticut and Louisiana, we find a reduction in thickness to 11 inches in the water-line belt, the 8-inch turrets are disposed quadrilaterally, the upper casemate armor is made 7 inches thick to protect the 7-inch guns. The general arrangement and disposition of the armor with the weights of each class are shown in Plate V.

63. The later vessels follow the general design of the Connecticut and Louisiana. The belt, however, is reduced to 9 inches in the Kansas class.

64. Distribution of armor on monitors.—It has been demonstrated that such craft are only efficient in smooth water. They are now considered only as a means of harbor defense, and as other methods are more efficient for the purpose, the type has been abandoned. Future design need not therefore be considered. As a matter of fact there has been no change in the principle of design, since the original monitor. The essential features are: A complete water-line belt of maximum thickness in wake of the machinery and magazine spaces, tapering to the ends; a deflective- and protective-deck, similar to that worked in battleships; turrets mounted on the center line, revolving in heavy barbettes.

Armored Cruisers.

65. The evolution of the armored cruiser from the New York and Brooklyn to the latest type represented by the Tennessee class, Plate VI, has developed what is in reality a battleship. To compare the Tennessee and Connecticut, for example, we find the same principles applied in the distribution of armor in the one as in the other; namely, a water-line belt 5 inches thick; casemate armor, continuous with the belt and of the same thickness, completely enclosing the broadside battery; protective-decks; turrets with 7-inch sides and 5-inch back, and 9-inch port-plates; 7-inch maximum on barbettes; splinter-bulkheads, conning-tower, armored tubes, etc., all being very much lighter in the armored cruiser than in the battleship.

66. Many are of the opinion that the limit has been reached in this type and that the logical principles of attack and defense, in warship design, which means using the most efficient weapon to the end, have not been exemplified in the modern armored cruiser.

67. Milwaukee type.—The Milwaukee type, called protected cruisers, but in reality armored cruisers, carry 4 inches of armor to protect the water-line amidships and the broadside battery, and the armor forms in effect a central citadel or casemate of uniform thickness extending from below the water-line to the upper deck and completely enclosing the central portion of the ship. This protection is supplemented by the usual protective-deck, cofferdams containing cellulose, and coal-bunkers.

68 Gun-shields.—Opinion is divided as to the efficacy of gun-shields for guns in positions unprotected by armor. On the one hand it is argued that such shields serve merely as means for bursting shell, thus menacing the personnel of the gun's crew, whereas without the shield, the shell would pass harmlessly by. Others maintain that it is better to be certain of defeating smaller caliber projectiles and take chances of being struck by shell that will pierce the shield.

69. If properly disposed, shields form the best possible protection for the guns.. The inclined port-plates of turrets are in reality shields. The round shields covering the guns in the re-entrant ports of the casemate guns in battleships are absolutely necessary as protection against fragments of shell.

70. In general it may be said to be good policy to fit shields to all guns where it is possible to make them sufficiently resisting to give complete protection against all shell of the same or less caliber than the gun to which the shield is fitted.

71. The prime function of armor, as applied to ships of war, is to keep out projectiles; and the qualities sought are, first, resistance to penetration and, second, a minimum tendency to cracking. With modern methods of securing armor, the importance of the latter is not so great as formerly; it is, however, an element of weakness in that it makes the plate more vulnerable to the next blow, so far as resistance to perforation goes.

72. The question of the racking effect on the structure of the ship and on the machinery, main and auxiliary, of the vessel is not now considered of great importance. Proving-ground experiments show that the shock of impact is dissipated by work on the projectile or is absorbed by the armor-plate and its supports.

TENDENCY OF BATTLESHIP DESIGN.

73. Armor serves two purposes; *first,* protection for the personnel, which involves that of the gun positions and armament, and *second,* protection for the flotability and interior mechanism of the vessel. The latter includes protection of the hull and machinery.

74. The armor-belt.—The present system in the United States is to protect the water-line area by an armor-belt about 8 feet wide, 3½ feet below the water-line and 4½ feet above, extending the whole length of the ship, of maximum thickness in wake of the machinery and magazine spaces, and tapering to about 4 inches at the bow and stern. This belt is supplemented by a deflective- or protective-deck, sloping from the bottom of the armor-belt, the whole length of the ship, flat in the center amidships, and crowned fore and aft as indicated on the type sketch of the Connecticut. There are also cofferdams filled with cellulose, and coal-bunkers. The principal function of the coal is to smother fragments of bursting shell, and its value as protection is only incidental.

75. Protection of personnel.—Modern methods of construction have so minimized the effect of a water-line hit that it is doubtful if it would be possible to seriously affect the stability or even the trim of a battleship by a single impact at the water-line. And the chances of such a hit are extremely small, as witnessed by the actions at the Yalu and during the Spanish War. Hence more importance is being attached to the protection of the personnel, so that we see a steady decrease in thickness of the water-line belt, and an increase in thickness of the casemates. It is generally agreed that the best method of protecting the heavy guns is to mount them in turrets rising out of heavily armored barbettes.

76. The casemate method of protecting the intermediate or broadside battery (guns of caliber less than 8 inches) has been used from the beginning of modern construction, but many well-informed officers believe that present direction of development will induce a more extended use of turrets.

77. Future design as regards armor-protection will be influenced by:

(1) *Increase in the caliber of broadside guns* (7-inch guns have recently been adopted for the broadside battery of the Connecticut), which will involve a commensurate thickness of armor for protection; and for guns above 7-inch caliber, perhaps mechanical appliances for operating.

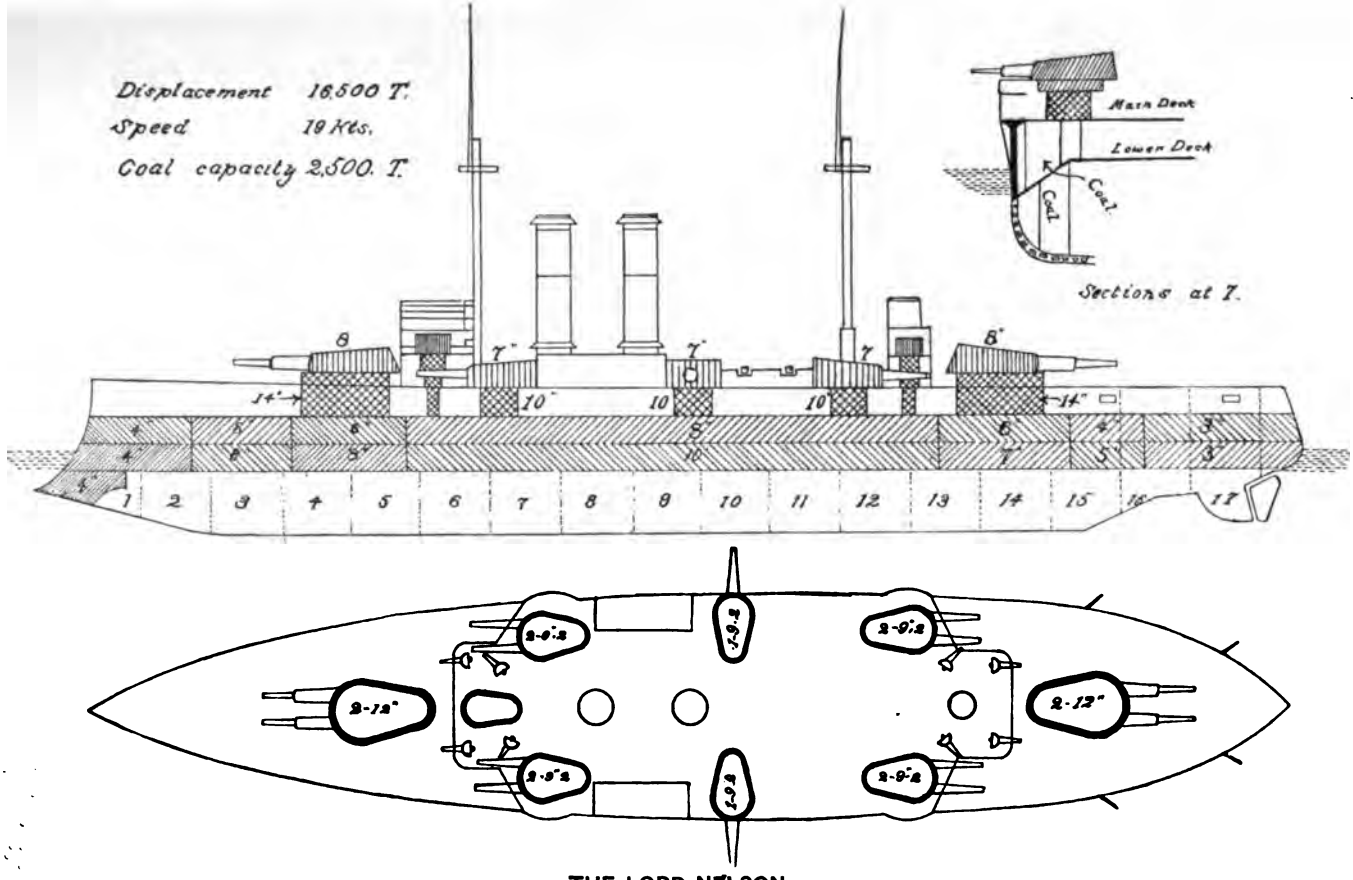
(2) *Improvement in the quality of A. P. projectiles* whereby a capped projectile, at any range within 3000 yards, and for the larger calibers than 6 inches at considerably greater ranges, will, if striking normally, perforate the best armor a caliber in thickness and burst inside. This will involve an increase in thickness of armor, or some method of inclining it beyond the biting or efficient angle of the cap.

(3) *Improved methods of construction* that minimize the danger to flotability and stability if struck in the water-line region, and limit the effect of bursting shell in portions of the ship other than gun-positions, which involves a decrease in thickness of water-line armor and a concentration of protection at the gun-positions.

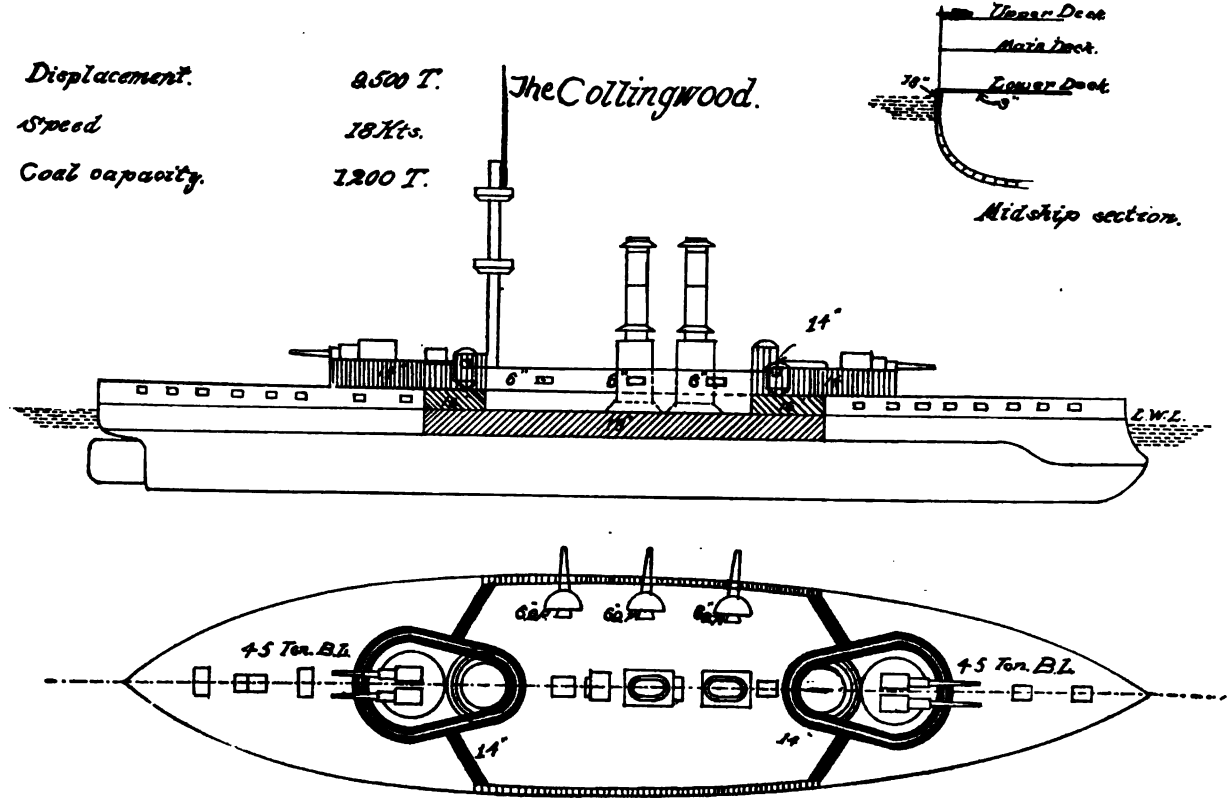
(4) *The use of electrical machinery* for sighting the guns and supplying ammunition, whereby it is possible to handle the larger caliber guns (above 6-inch or 7-inch), with great ease and nicety, so that it is not too much to hope to get as good results in the matter of rapidity and accuracy of fire as could be obtained from the smaller caliber guns handled by hand.

(5) *Possible improvement in the quality of armor.* It is doubtful, however, if such improvement will keep pace with the gun and projectile.

78. Turrets.—All these considerations would, so far as armor protection goes, seem to point to a more extended use of turrets, with inclined port-plates. In the matter of armor disposition the present design of turret could hardly be improved upon, having



THE LORD NELSON.



THE "ADMIRAL" CLASS (BRITISH, 1882).

its port-plate inclined at an angle beyond that at which projectiles will bite, and with minimum openings for the gun.

79. Recent foreign designs—Lord Nelson class.—The foregoing paragraphs were written early in 1903. Since then various causes have operated to produce a type of ship which may be expressed in the design of the British "Lord Nelson" class. These influences have been: The improvement in gunnery whereby increased rapidity and accuracy of fire have been attained by heavy guns; the development of the torpedo, making it a weapon to be considered within 4000 yards; and, finally, the realization, in the light of the recent events in the war between Japan and Russia, that decisive engagements may be fought at ranges of from 6000 to 8000 yards. Thus a ship must be designed for a long-range action and we have, as a type, a ship with a battery of heavy guns; four 12-inch, mounted in pairs in turrets forward and aft, eight 9.2-inch guns, mounted in turrets quadrilaterally, and two 9.2-inch in single turrets between the double turrets that contain the other guns of this caliber; all guns are mounted over heavy barbettes. Thus, with the passing of the 6-inch and 7-inch guns, and the *adoption of guns of the heavy class for the intermediate battery, the casemate or central-citadel system becomes obsolete,* and we find all, save minor-caliber guns, mounted in turrets. So that within a very short time we may expect to see laid down battleships having a *homogeneous battery of heavy guns mounted in turrets.*

TYPES OF BATTLESHIPS.

80. Definitions.—The various terms used to designate gun-positions may be defined as follows:

(1) **Turret.**—A revolving armored structure in which a gun or a pair of guns are mounted; the guns revolve with the turret and are completely enclosed save for the chase of the gun which projects through a port-hole in the front plate of the turret.

(2) **Barbette.**—A fixed circular structure, built up of armor-plates, which protects the mechanism and the ammunition supply of the gun or of the turret containing the gun mounted above it.

(3) **Casemate.**—An isolated gun-position for a broadside gun with fixed armor-protection, which completely encloses the gun

save for a port-hole through which the muzzle projects. The sides and rear are of comparatively thin armor, designed to confine the effect of an entering projectile to that one gun-position and to stop the fragments of such shell as may burst on the deck outside.

(4) **Central citadel.**—Armor enclosing a series of broadside guns. The emplacement is sometimes called a "box-battery." Splinter-bulkheads may or may not be worked between the guns; in either case, it may be designated a continuous battery position. When the bulkheads are extended so as to completely enclose each gun, each gun-position is in effect a casemate.

81. Development of battleship design in the United States.—The classification of battleships is of course more or less arbitrary, but as a rule they are designated by the character of the gun-positions of their heavy guns. Thus we have successively in the U. S. Navy:

(1) The original turret ship—the Monitor of the Civil War.

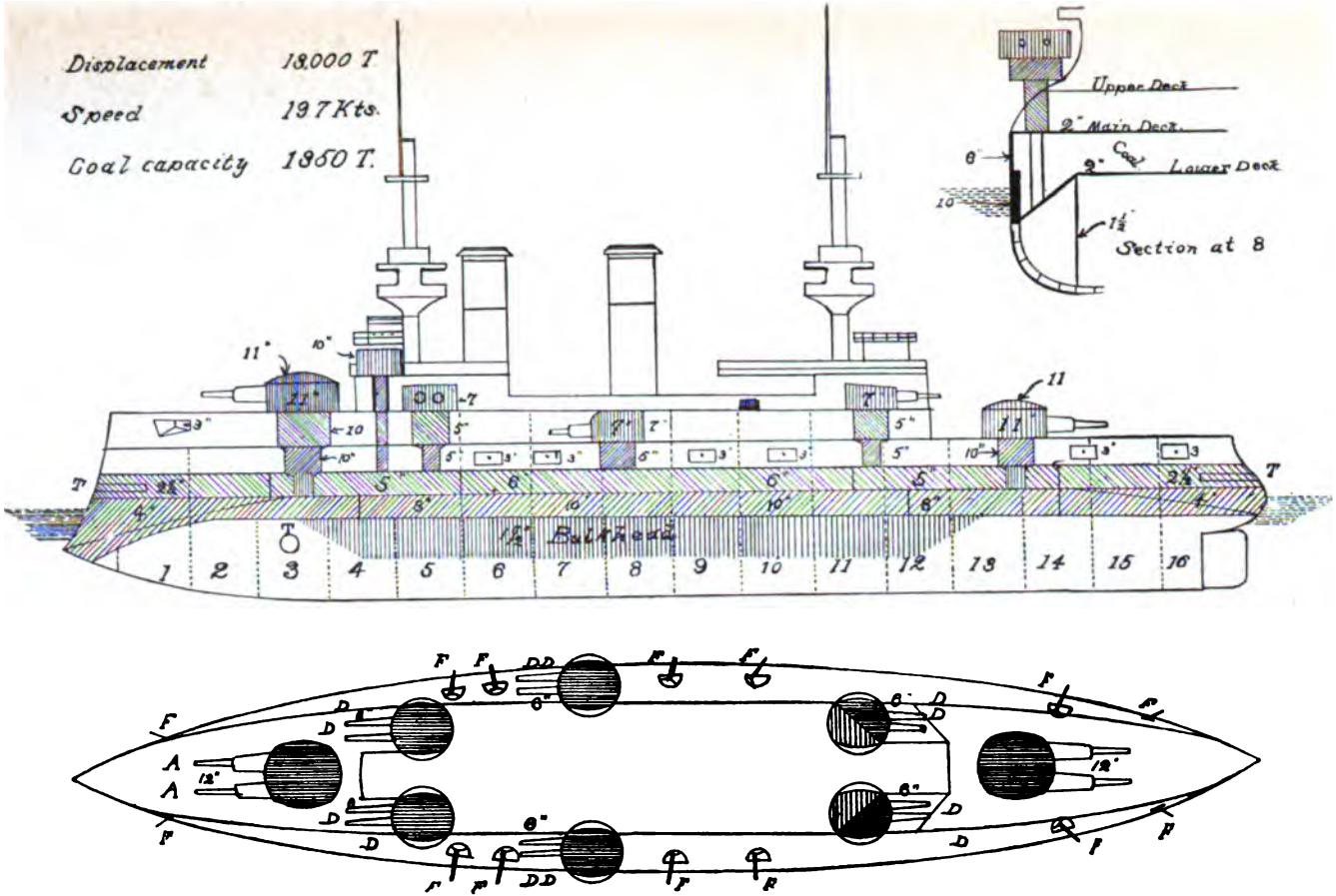
(2) Then the later monitors such as the Amphitrite, 1883, with narrow barbettes under their turrets.

(3) Then the barbette-turret vessels of the Indiana class, in which the Iowa may be included. All subsequent battleships may also be termed *barbette-turret ships,* modified by the character of their intermediate and secondary-gun positions. The Indiana class are 13-inch barbette-turret ships, with 8-inch turrets, mounted quadrilaterally over narrow barbettes, ammunition tubes to protect the 8-inch supply, and local protection for the four 6-inch guns.

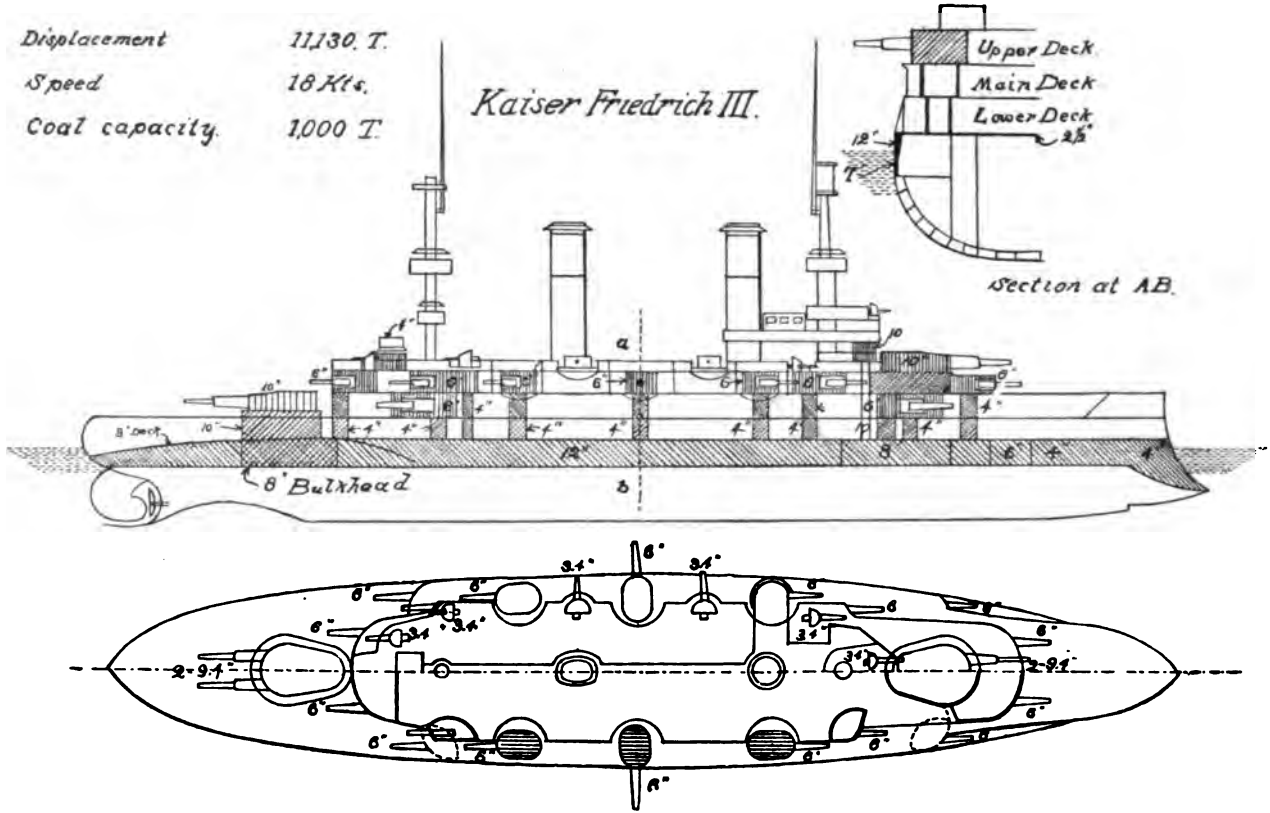
(4) The Kearsarge may be described as a barbette-turret vessel, with superposed 8-inch turrets and a continuous or box-battery of 5-inch guns enclosed in a central citadel or armored redoubt.

(5) The Alabama and the Maine are barbette-turret ships with continuous batteries of 6-inch guns, having partial splinter-bulkheads between, enclosed in armored central citadels.

(6) The Virginia is a barbette-turret ship with superposed 8-inch turrets, two broadside 8-inch turrets, mounted over narrow barbettes and ammunition tubes, and a continuous battery of 6-inch guns, separated by splinter-bulkheads, enclosed in a central



THE CZAREVITCH (RUSSIAN, 1901).



THE "KAISER" CLASS (GERMAN, 1898).

citadel which is divided longitudinally by an armored-bulkhead in line with the keel.

(7) The Connecticut and Kansas classes may be designated the same as the Virginia, except that all the 8-inch guns are mounted in turrets arranged quadrilaterally, and the splinter-bulkheads practically enclose each of the 7-inch guns.

82. Water-line armor.—In the matter of water-line armor, the American practice has been the same as that of the British:

(1) First, as in the Indiana class, with a heavy belt between the heavy gun-positions, the ends being unarmored and the space between the main and lower decks being protected by thin armor, called the lower casemate armor.

(2) In the Kearsarge the water-line armor is extended to the bow, tapering to four inches, and the casemate armor is carried to the upper deck, the upper strake being called the upper casemate armor. The casemate armor is extended inward, diagonally, at its ends; diagonal armor also joins the barbettes to the belt.

(3) In subsequent ships, the same system is followed, save that, beginning with the Virginia class, the belt-armor along the water line is extended, tapering, to the stern.

83. In the U. S. Navy there have been no barbette ships and no casemates proper for the intermediate guns. Characteristic American features of design have been the adoption of turrets and the use of semi-heavy guns in turrets.

84. Practice in the British Navy.—Modern British battleships began with the Admiral class, in 1883, shown in Plate VIII.

(1) This is a type of barbette ship, with no redoubt or casemate armor.

(2) Then came the Trafalgar, in 1888, with a lower redoubt or central citadel.

(3) The Centurion class followed, in 1892; these are barbette-turret vessels similar to the Indiana, save that they have 6-inch guns mounted in isolated casemates in the place of the 8-inch turrets of the latter.

(4) The British retained the barbette turrets for heavy guns and followed the isolated casemate system for the intermediate battery until the King Edward class was laid down in 1903.

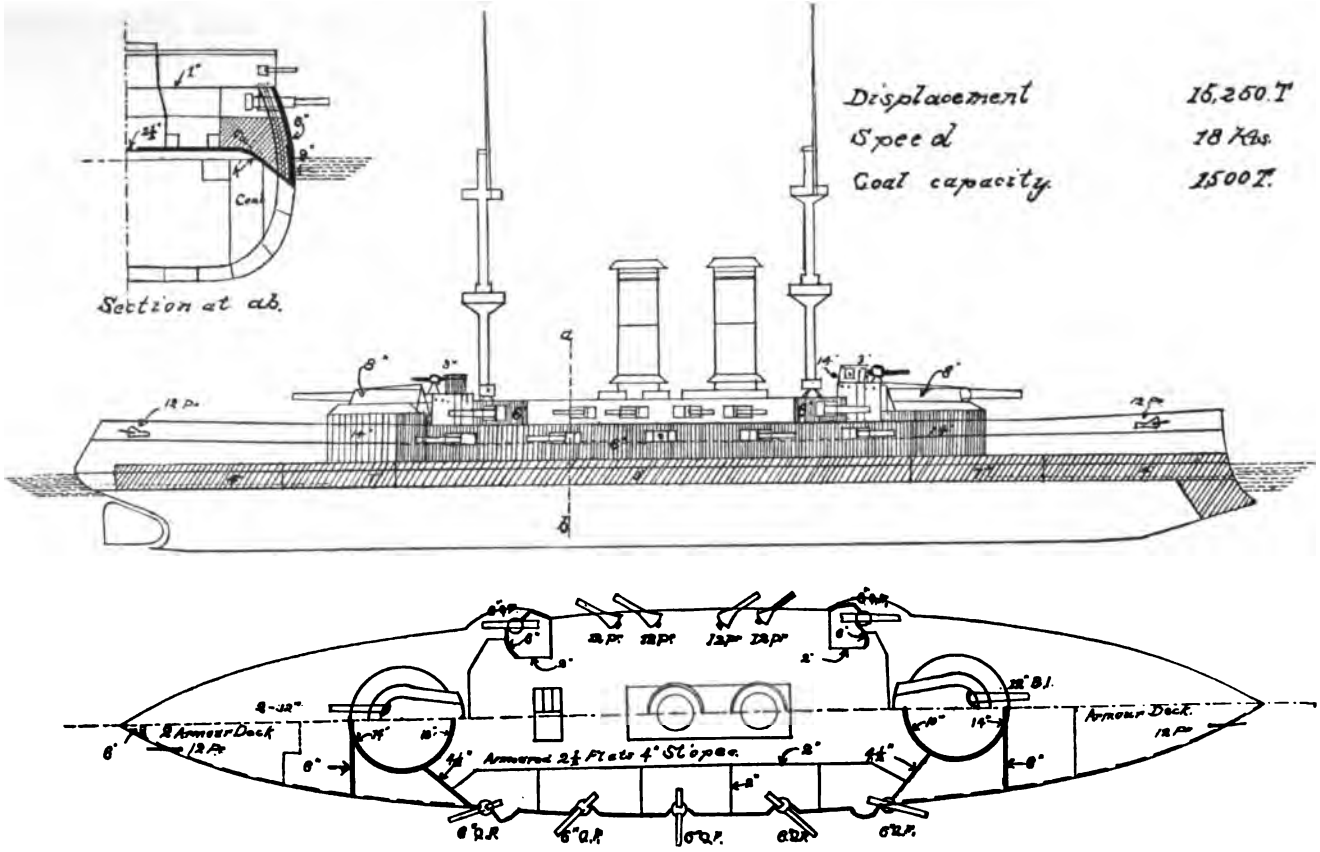
These ships are similar to the Connecticut but have four quadrilateral turrets, each containing a single 9.2-inch gun, in place of the four twin 8-inch turrets of the latter and have 6-inch box-batteries, with enclosing splinter-bulkheads, instead of the 7-inch battery of the American ship. Also, in the King Edward the lower deck casemate is carried to the bow.

85. Beginning with the Canopus, the belt armor of British ships extends to the ends, following the French practice, tapering from the barbettes. A short description and preliminary sketch design of the Lord Nelson is given in Article **79.** It will be noted that the British have come to the consistent French types—as they did in their armored cruisers of the Warrior class. Characteristic features of British battleship design may be said to have been unarmored ends and the use of casemates for the intermediate battery.

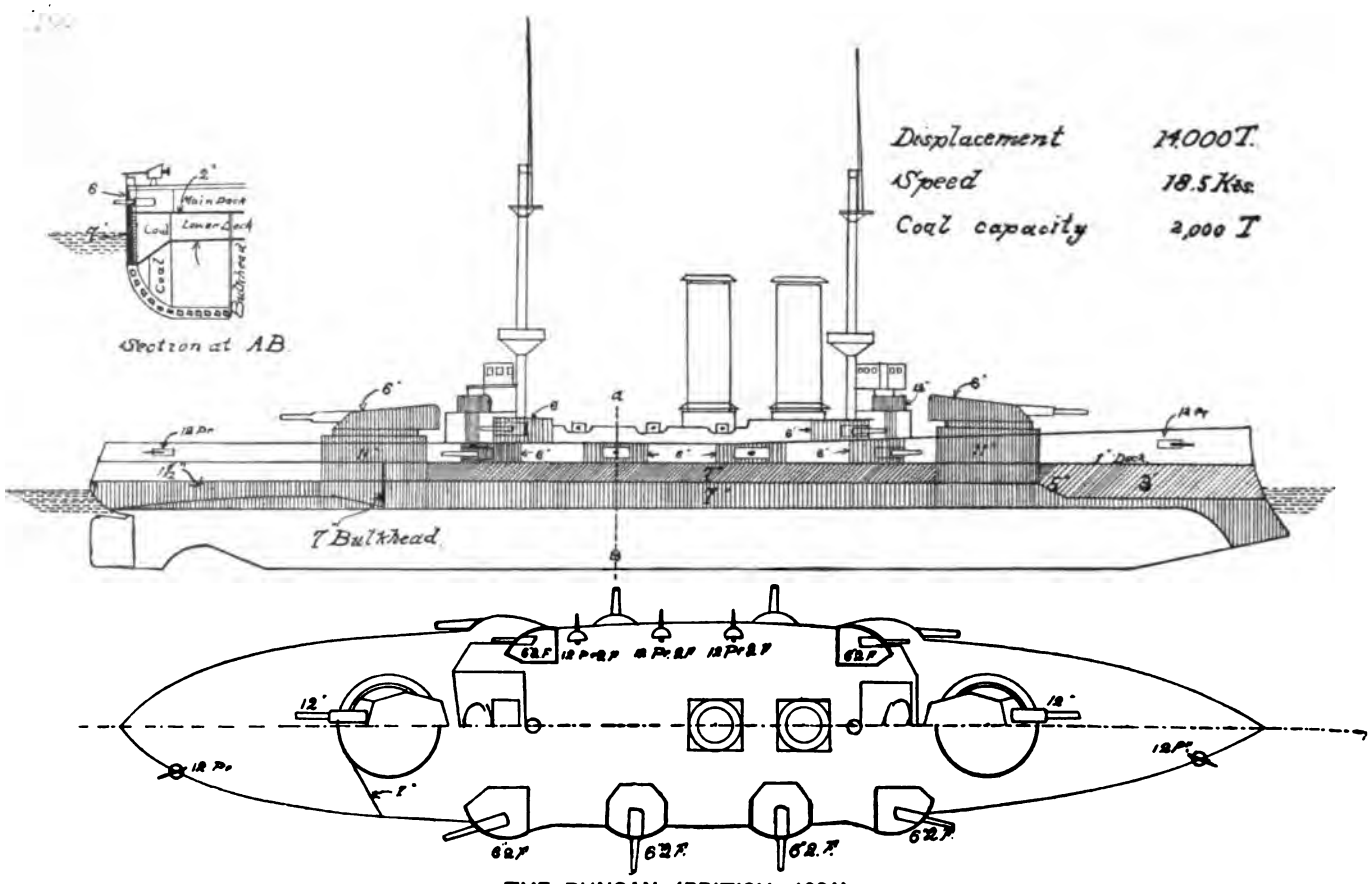
86. French types.—The French in all their designs have persistently adhered to certain peculiar features, namely: (1) a continuous water-line belt, (2) the use of turrets for the intermediate battery, (3) extension of the lower deck or casemate armor to the ends, and (4) the omission of all armor except that for ammunition-tubes, etc., between the main and upper decks. Plate IX illustrates the Czarevitch, a Russian battleship of French design, constructed in a French shipyard.

87. German battleships have had no distinctive characteristics. As a rule, they are smaller and more lightly armed and armored than are contemporary vessels of the United States, Great Britain, or France. This is due to the necessity of keeping down the displacement, on account of the German harbors. Plate X illustrates the Kaiser class; a peculiar feature is the use of ammunition-tubes for the 6-inch casemates; this is necessary because the casemates are not, as in most casemate ships, built directly over lower-deck casemate-armor, but are above an unarmored space.

88. Italy.—The early Italian battleships were remarkable for their big 100-ton guns. Their later designs have always been well thought-out and adapted to the necessities of their fleet and harbors. Their latest type is a 20-knot battleship with remarkably strong battery and fair armor protection. This is the Vit-



THE MIKASA (JAPANESE, 1900).



THE DUNCAN (BRITISH, 1901).

torio Emmanuel class, and is a combination of the battleship and armored cruiser.

89. The Russians, it may be said, have in general followed French ideas. The design of the Czarevitch has been copied, with some improvements for the several ships which they have now under construction or newly commissioned.

90. The Japanese have adopted the British designs, usually improving upon them, and all their battleships have been built in England. Plate XI shows the best of the Japanese battleships, the Mikasa; she is mainly different from the typical British ship in the protection of her 6-inch guns, there being a continuous wall of armor in front of those on the lower deck as well as complete protection in rear by splinter-bulkheads. The Duncan, of which class there are many in the British Navy, is shown by Plate XII; these are typical casemate ships and were commissioned at about the same time as the Mikasa.

CHAPTER XXXII.

PENETRATION OF PROJECTILES.

By Lieutenant-Commander Cleland Davis, U. S. Navy.

1. General discussion.—When a projectile strikes a target, and its motion is destroyed, its energy must be dissipated by (1) heating the target; (2) heating the projectile; (3) changing the form of the projectile; (4) changing the form of the target. All of these but the last are, from the artillerist's standpoint, a waste. The amount of energy which takes the form of heat in the projectile and target is not known, but could be approximately ascertained by the use of bodies which ignited or fused at known temperatures. It is known that the temperature of the shell is sufficiently great to ignite the bursting charge (540° F.), and this indicates an amount of energy which must have been reached or exceeded. A bright red spot, even on bright days, can be observed at the point of impact at the instant the projectile strikes the plate, which shows that the plate in the immediate vicinity of the impact is heated to a high degree of temperature.

2. No accurate experiments have as yet been carried out in order to determine the coefficients of resistance for the different materials of projectiles and plates, so that it is difficult to study the subject in a rigidly mathematical way. But the amount of penetration, whether for iron or steel plates, masonry, or for earth, has been determined practically by experiment. A number of formulas have been proposed, based on various hypotheses, and which agree more or less closely with the results obtained in actual firing. The diversity of the formulas proposed testifies to the difficulty of expressing the law of resistance of armored shields to perforation; and it is very doubtful if it be possible to express this law by an exact formula, since the resistance of the

plates and the power of projectiles to overcome that resistance depend on so many conditions that escape calculation. Plates vary in different factories; the same factory cannot always deliver plates exactly alike, and any single plate is not perfectly homogeneous. The same may be said, to a less degree perhaps, of the projectiles; in addition may be mentioned the variation in shape of the projectile on impact, the possibility of the projectile breaking up, and the amount of heat developed on impact; all of these varying conditions make it practically impossible to apply strictly analytical investigations and deduce a law which will stand the test of general application.

3. The penetrative effect.—Generally speaking, the penetrative effect depends on the shape and material of the projectile, on its energy, diameter, and the direction in which it strikes the target.

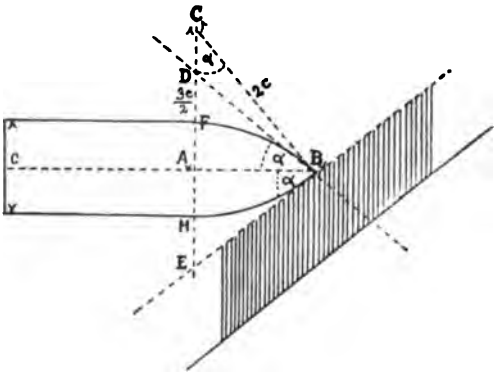
4. Form of head.—Several forms of head have been extensively experimented with, viz., flat, ogival, hemispherical, and conoidal. For piercing plates by shot striking normal to the surface of the plate, the ogival head of two to two and a half diameters is considered to have given the best results.

5. The steel cap.—A soft steel cap is now being fitted to all A. P. projectiles. This cap is in diameter about half the caliber of the projectile, and is about 4 per-cent of the weight. Its action is fully explained in the preceding chapter. It adds about 15 per-cent to the efficiency of the projectile with respect to the thickness of the plate and about 20 per-cent with respect to the striking velocity.

6. Material.—Chilled iron, wrought-iron, and steel have been experimented with to ascertain their respective merits for materials to make projectiles for piercing armor-plates. Although chilled iron has been used on account of its easier manipulation, its great hardness, and its cheapness, the best material for projectiles to pierce armor is that which will neither break up on impact nor change its shape; a forged oil-tempered steel of special treatment and of special alloy fulfills these conditions better than any other metal.

7. Various elements have been and are used to alloy the steel in order to obtain the requisite qualities for a good armor-piercing

projectile; these include principally nickel, chrome, manganese, and tungsten, which are combined in various ways to produce the desired results, namely a maximum of hardness combined with a maximum of toughness.



ART. 10. THE BITING ANGLE.

The figure shows the shell striking the plate at the *biting angle*, i. e., with the tangent EB in the plane of the plate's surface. Radius of ogival two calibers.

$$CB = 2c = \text{radius of arc HB} \quad . \quad AC = \frac{3c}{2}.$$

The angle ACB = ABE = the *biting angle*, a, because its sides are perpendicular, respectively, to AB and BE.

From the triangle, ABC, $\cos a = \frac{\frac{3c}{2}}{2c} = \frac{3}{4} \therefore a = 41° - 24' - 30''$.

From the above it will be seen that the value of a may be expressed as follows:

$a = \cos^{-1} \frac{n - \frac{1}{2}}{n}$ where n = radius of the ogival in calibers.

Thus, for $n = 2\frac{1}{2}$, $a = \cos^{-1} \frac{4}{5} = 36° - 52'$.

$n = 2$, $a = \cos^{-1} \frac{3}{4} = 41° - 24' - 30''$.

$n = 1\frac{1}{2}$, $a = \cos^{-1} \frac{2}{3} = 48° - 11'$, etc., etc.

8. Change of shape means a loss of energy uselessly expended in heating the projectile, and if the projectile breaks up, it gen-

erally fails to impress all its energy on the armor-plate. Tough steel more nearly answers the requirements for armor-piercing than any other metal. Forged steel is better than cast-steel, as it does not break up on impact; and if the power of the armor for resistance nearly equals the power of the projectile for penetration, it is the only metal that will carry a bursting-charge through the plate. With nickel-steel armor, Harveyized, or with Krupp-process armor, it is even more necessary to have forged steel projectiles of special treatment and of special alloy, since experiments show that those constructed of other materials break up on impact.

9. The best weight for a projectile of given diameter is generally found by giving a value to the ratio of $\frac{W}{d^3}$, where $W =$ weight of shot, $d =$ diameter. The latest researches give .45 to .5 as the value of this ratio. Thus for a 6-inch gun the weight would be not less than 97 pounds.

10. The biting angle, non-cemented steel.—It is evident that the point of an ogival-headed projectile will not bite thick armor at a less angle than that made by the tangent to the projectile at its point and the axis of the projectile. This will be seen from an inspection of the figure, and this angle is called the *biting* angle.

11. If the plate is of comparatively soft metal, such as wrought-iron and low steel, the shot will bite at a slightly less angle, owing to the fact that the plate bends slightly on impact and increases the angle between the tangent and the surface.

12. For face-hardened armor, the biting angle cannot be mathematically stated. In general, it may be defined as that angle at which the component of the energy of the projectile, normal to the plate, is sufficient to smash in the hard face, the projectile at the same time holding together long enough to effect an entrance.

13. It has been experimentally demonstrated at the Proving-Ground, heads of various shapes having been used, that the flat-headed projectile is the superior of all others, at short ranges, against armor inclined at small angles to the line of fire.

14. Biting angle of the cap.—Proving-ground experiments have demonstrated that the cap is not efficient at angles of impact

above 25 degrees to the normal. In other words, this is the biting angle of the cap. Taken in connection with the theory of the cap, the reason of this is susceptible of explanation. Assuming that the normal component only of the total striking energy is useful in smashing the hard face, there is a point at which this component is not sufficient to give the desired result, so that the effect is the same as if the projectile were not capped. A 6-inch capped projectile striking a 5½ Krupp hard-faced plate at an angle of 45 degrees, with velocity of 2137 f. s., punched a hole in the plate, but the projectile, with part of its ogive sticking in the hole, remained in front of the plate.

Empirical Formulas for Penetration.

15. For thin plates which can easily be penetrated, experiment seems to show that the projectile acts as a punch, cracking the plate *circumferentially,* at the same time bulging it on the inside, where it also commences to crack. In this case the method of estimating the resistance per inch of projectile's circumference gives good results, but in cases where the projectile acts as a wedge, and drives the resisting material before it, the method of estimating the resistance per square inch of sectional area gives approximately better results. The truth probably lies between the two, inclining the more to the one or the other according as a punching or wedging action is brought into play.

16. The following formulas, by Th. Jacob de Marre, Capitaine d'Artillerie de la Marine, France, are those now in use, and have been deduced from the results of experience.

In these formulas,

v = striking velocity in f. s.

p = weight of projectile in pounds.

c = diameter in inches.

E = thickness penetrated in inches.

The quantities in brackets are the logarithms of constant .

(1) For penetration of wood backing.

$$E^{0.6} = [7.79013 - 10]\frac{p^{\frac{1}{2}}v}{c^{0.5}}. \qquad (1)$$

(2) For penetration of wrought-iron,

$$E^{0.66} = [7.03838 - 10]\frac{p^{\frac{1}{2}}v}{c^{\frac{3}{2}}}. \qquad (2)$$

(3) For penetration of thin steel plates, not Harveyized, by steel shell from 6-pounder R. F. guns, and smaller calibers,

$$E^{0.7} = [6.86572 - 10]\frac{p^{\frac{1}{2}}v}{c^{\frac{3}{2}}}. \qquad (3)$$

(4) For penetration of thick plates, not Harveyized,

$$E^{0.7} = [6.99066 - 10]\frac{p^{\frac{1}{2}}v}{c^{\frac{3}{2}}}. \qquad (4)$$

17. To find the striking velocity necessary to penetrate a given thickness of plate and backing, solve the proper formulas for v. If v_1 is the striking velocity necessary to penetrate the plate, and v_2 the striking velocity for the backing, the required velocity is

$$v = \sqrt{v_1^2 + v_2^2}.$$

18. The use of formula (4):

* "Formula (4) can be put in the form

$$v = K\frac{c^{\frac{3}{2}}}{p^{\frac{1}{2}}}E^{\frac{1}{6}}.$$

It is still used to represent the average resistance to the armor-piercing projectile when it penetrates the armor-plate without being deformed, the plate being oil-tempered and annealed. The value of K is 1022. for practical purposes.

19. With a face-hardened plate it has come to be the practice to use this formula with its velocity, or the thickness of the plate multiplied by some factor. For some time, for example, our government shot at plates as if they were 1.15 times their thickness, but at present it is the practice to multiply the velocity as derived from de Marre's formula, as formula (4) is called, by a factor, which factor has been 1.38 on thin plates of 5 inches and 6 inches in thickness, and about 1.30 on thick plates of 12 inches to 15 inches in thickness. These factors are used only in the case

* Discussion by J. F. Meigs, Artillery Engineer of the Bethlehem Steel Co.

of Krupp-process plates. With ordinary hard-faced plates, which were called Harvey plates, the factor could not reach so high a value.

20. The difficulty of measuring resistance of the hard-face plate is much greater than in the case of the soft plates, because it becomes largely a question between the temper of the plate and the projectile.

21. If the temper and toughness of the projectile could be made perfect they would unquestionably penetrate the existing armor-plate, but in existing armor-plates the hard face is relied upon to destroy the projectile and thus prevent its penetration. It will be noted that the head and point of the projectile are hard and its base end soft and tough, and that it presents itself in just the same way to the impact as does the plate."

22. Recent formulas.—Other formulas for the penetration of both homogeneous and face-hardened armor have been proposed both in this country and abroad, but the de Marre formula is the one on which ballistic tests are based universally, and this is of value to all governments in that it affords a basis of comparison as to the quality of armor each is getting.

23. The following formulæ were deduced by Lieut. Cleland Davis, U. S. Navy, from experiments made under the direction of the Bureau of Ordnance, for the perforation of Harveyized Armor:

Projectiles without caps.	Capped projectiles.
$V = \frac{c^{\frac{1}{2}}\, \epsilon^{\frac{1}{2}}}{p^{\frac{1}{4}}} K$ (1)	$V = \frac{c^{\frac{1}{2}}\, \epsilon^{\frac{1}{2}}}{p^{\frac{1}{4}}} K'$ (2)

$\log K = 3.34512$, $\log K' = 3.25312$ using notation as before.

In these, the thickness of armor given just matches the velocity, so that under normal conditions of plate and projectile the latter would just get through, being itself destroyed in so doing.

24. No satisfactory formula has yet been deduced for the perforation of Krupp armor. For capped projectiles, however, a fairly close approximation may be obtained by adding a constant of from 100 to 150 foot-seconds to the velocity obtained from (2).

NOTE.—See table at end of this chapter.

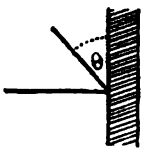
12-INCH ARMY SERVICE RIFLE TARGET. FIRST ROUND. Front of Plate.

12-INCH ARMY SERVICE RIFLE TARGET. FIRST ROUND. Back of Plate.

25. The velocities for the acceptance test of projectiles by the Bureau of Ordnance are based upon (2).

26. For uncapped projectiles, a fair approximation may be obtained for plates equal in thickness to the caliber of the attacking gun by adding 200 to 250 f. s. to the velocities given from formula (1).

27. Oblique penetration.—When a target is penetrated by oblique fire, it is generally found that the projectile turns and penetrates nearly normal to the plate. The normal velocity is then $V \sin \theta$, if θ is the biting angle with the face of the plate. In formulas in which V is used, the value $V \sin \theta$ must be substituted.



Kinds of Projectiles.

28. Three kinds of projectiles are in use in the U. S. Navy for the large caliber guns: Armor-piercing, common or semi-armor piercing, and shrapnel. As a rule the latter would only be used in the attack of exposed bodies of men. The specifications for the former require that armor-piercing shell shall perforate face-hardened armor-plate of thickness equal to the caliber, and remain in a condition for effective bursting. Semi-armor piercing, or forged-steel shell, must pass through half a caliber of face-hardened armor and remain in a condition for effective bursting.

29. It has recently been announced that the Bureau of Ordnance has decided to abandon the semi-armor piercing shell and to adopt one type that combines the qualities of both A. P. and S. A. P. projectiles. Recent developments have shown that it is possible to produce a shell that, loaded with black powder, will perforate hard-faced Krupp armor, one caliber in thickness, at velocities corresponding to ranges of 3000 yards for the 50-caliber 6-inch, up to 6000 yards for the 40-caliber 12-inch, remaining whole, and at the same time, have such capacity of cavity as to give a well conditioned burst.

Development of High Explosive Shells.

30. Great Improvements have recently been made in armor-piercing shell, and the fact that it is possible to send an armor-piercing shell loaded with a high explosive through a thickness of plate equal to its caliber and detonate it behind the plate may result, eventually, in the adoption of such shell for the Navy.

31. Test of high explosive shell.—The most striking example of this result was in the test of the 12-inch Army rifle in comparison with the 18-inch Gathmann Torpedo Gun. This test marked such an important advance in the attack on armor that the result is given in full together with photographs. The target was an 11½-inch Krupp plate, 16 feet long by 7½ feet wide attached to a structure which represented a section of the side of the Iowa.

32. *Round one.*—An armor-piercing shot weighing 1001 pounds and 7 ounces, including 19 pounds 7 ounces of army high-explosive, struck the center of the target with a velocity of 1800 feet per second, corresponding to a range of 4400 yards. The striking energy was 22,500 foot-tons. This shot penetrated the plate and was detonated just in the rear. The backing, the skin plates, frames, and cofferdam plates were completely demolished in the line of this impact. The crater formed in the sand butt in the rear of the structure measured 15 feet by 6½ feet. Pieces of the plate and projectile passed through the structure, through the butt, and were recovered at distances of 150 to 200 feet in rear of the butt. The rivets in the top plate were sheared, the side plates of the cofferdam were buckled about 3 inches, and the plate was forced back bodily about three-fourths of an inch. See Plates I and II.

33. *Round two.*—An army 12-inch armor-piercing shot weighing 1006 pounds, including 23 pounds of Maximite, struck the right center of the plate with a velocity of 1804 feet per second, corresponding to a range of 4400 yards. The striking energy was 22,500 foot-tons. The shot detonated in the plate, completely wrecking the right-hand portion and demolishing the frames behind the armor and the plates of the cofferdam. See Plates III and IV.

12-INCH ARMY SERVICE RIFLE TARGET. SECOND ROUND. Front of Plate.

12-INCH ARMY SERVICE RIFLE TARGET. SECOND ROUND. Back of Plate.

34. *Round three.*—A 12-inch armor-piercing shell weighing 1045 pounds, including 60 pounds of army high-explosive, struck the lower left-hand center of the plate with a velocity of 2073 feet per second, corresponding to a range of 1880 yards. The striking energy was 31,100 foot-tons. The shell penetrated and detonated in the plate. As a result of this impact the plate was totally wrecked and the backing, frames, beams, and cofferdam plates of the structure were completely demolished. An opening was made through the plate 4 feet wide by 8 feet long.

35. The lower left-hand quarter of the armor-plate was broken into six large fragments and numerous small ones, the largest being about 4½ feet square, which, with the backing and skin plates, was torn loose from the structure and turned inward, so that the left-hand edge of this fragment was in the plane of the original face of the plate. One large fragment about 2 feet by 2½ feet by 11½ inches, and weighing about 2500 pounds, was hurled through the target, through the butt, and was recovered 135 feet in the rear of the butt. Numerous fragments of the plate and projectile passed through the target structure, through the butt, and were recovered in the rear. The effect of this shot would have resulted in serious injury to a battleship (see Plate V). The comparative harmlessness of the Gathmann shell loaded with 500 pounds of gun-cotton when exploded against a similar plate was due to the fact that the shell did not penetrate but simply exploded outside and in contact with the plate.

36. No academic rules can be laid down as to methods of attacking armored vessels. There are now but two classes of projectiles available, the armor-piercing and the common or semi-armor piercing. All the former are now being filled with bursting-charges, and the quality is being so much improved that those that will in future be issued to the service will possess the perforating power of the present armor-piercing shell and at the same time have sufficient capacity for well-conditioned bursting. Assuming that the object is to explode the shell on the inside of the enemy's vessel, the rule would be to use whatever could accomplish that object.

The Attack of Armored Ships.

37. The use of torpedoes, being weapons designed for the attack of armored ships, can properly be discussed here, in a general way. It has been proposed to armor the bottoms of battleships above the turn of the bilge, as a protection against the effect of the explosion of torpedoes; experiments have shown, however, that the armor would have to be so thick, in order to be effective, that its weight makes it prohibitive,—when the great extent of surface to be armored is considered. Therefore, other means, such as cellular bottoms and numerous water-tight bulkheads, are used to minimize the effect.

38. On torpedo boats and submarines the torpedo is a weapon of surprise and on battleships it is one of occasion. In a single action it would hardly be probable that battleships would get near enough to use their torpedoes, except toward the end of the engagement. In fleet actions it would be used within the limits of its range and might be fired at random at the enemy's fleet, taking chances of its hitting.

Of course, if only one type of projectile were issued to the service, the question would resolve itself into what portion of the enemy to attack, if the range were such that this would be within the limitations of gunnery.

39. Experiences of modern warfare.—The battle of the Yalu of the China-Japan war, battles of the Spanish-American war, and the recent naval actions in the war between Russia and Japan, afford the only experiences of recent years in which armored vessels have been engaged.

40. In the battle of the Yalu, the heavy armor of the Chinese battleships was not materially damaged, and so far as the life of the ships was concerned, they were effective at the close of the battle.

41. At the battle off Santiago, between the Spanish armored cruisers Maria Teresa, Oquendo, Viscaya and Colon, and the United States fleet, the Spanish cruisers, except the Colon, were totally destroyed, not by the piercing of their side armor, but by the destruction of their unarmored parts by the terrific effects of

12-INCH ARMY SERVICE RIFLE TARGET. THIRD ROUND. Front of Plate.

ACCEPTANCE TEST. 4-INCH PLATE.

shell fire and by the fires created by bursting shells. The side armor, so far as is known, was not pierced, but the upper works, battery-decks and all unarmored parts were riddled and torn to pieces, by the fire of common shell principally, the wood work being set on fire, fire-mains and hose cut, the crews demoralized with great loss in killed and wounded; the ships finally being run ashore. The Colon was run ashore and surrendered after being hit but six times without material damage, in her attempt to escape by flight.

42. The conclusion reached is that there should be greater protection for the gun-positions in armored cruisers than obtained in the Spanish ships, that isolated gun-positions are a necessity, that the chances of penetrative hits on water-line armor, except in very close actions is small, and that wood and inflammable material must be reduced to a minimum in ship construction.

43. The fight between the Russian and Japanese fleets after the sortie from Port Arthur, on August 10, 1904, is the only important battleship action fought up to the close of the year 1904. The accounts of the action are meagre but it seems that six Russian battleships, three armored cruisers, one protected cruiser, and eight torpedo boats were engaged by four Japanese battleships and a number of cruisers and torpedo boats. The Japanese ships possessed superior speed and were enabled to choose the range, which they never permitted the Russians to reduce below 6000 yards. As a result of the action, five of the Russian battleships were driven back into Port Arthur, though none of them were very seriously damaged. The sixth, the Czarevitch, was struck by several 12-inch shells and a number of shell of smaller calibers. These were nearly all explosive shells and did no damage to armored portions of the ship; she was not seriously injured, though her speed was considerably reduced by the destruction of her funnels; her steering wheel was temporarily jammed and her compasses deranged. During the night, she was surrounded and repeatedly attacked by Japanese torpedo boats, but without effect, and on the following night she steamed into Tsungtau.

44. From this battle it would appear that modern battleships may engage at very long ranges. Another important point to be

observed is the failure of the torpedo boats in the attack of a ship under way, even while they were operating at night. This latter circumstance, while casting serious doubt upon the value of the torpedo, cannot, however, be said to fix its capabilities, because the efficiency of the attacking boats and the ability of their crews in handling the weapon, are not known.

45. The battleship has again established its pre-eminence as the most effective type of naval vessel.

Outside Explosions.

46. The use of high explosives in the form of the aerial torpedo in the attack on armor formerly had many advocates, but recent experiments have shown that this method is not efficient. In November, 1901, at Sandy Hook, N. J., a Gathmann 18-inch aerial torpedo was fired from an 18-inch powder gun, especially constructed for the purpose, at an 11½-inch Kruppized armor-plate. The projectile weighed 1834 pounds, including 497 pounds of wet gun-cotton, and the fuse was so designed as to detonate the mass of gun-cotton upon impact. The impact was at a velocity of 1650 foot-seconds, corresponding to an energy of 34,610 foot-tons. The gun-cotton detonated on striking the plate, and the effect on the plate due to the explosion was nil. The plate was attached to a structure built to simulate a section of the side of a battleship, and the effect of the explosion on the structure seemed to indicate that the detonation of 500 pounds of high explosion against the armored side of a battleship would not seriously affect the structure of the vessel. Two succeeding impacts of projectiles containing the same amount of explosive confirmed the result of the first round.

NOTE.—Plates VI to XI inclusive, with the following explanatory table, furnished by the courtesy of the Bethlehem Steel Company and published by permission of the Bureau of Ordnance, give the details of recent acceptance tests for armor-plates for the U. S. Navy.

ACCEPTANCE TEST. U. S. ARMY GUN-SHIELD.

ACCEPTANCE TEST. 6-INCH PLATE.

BETHLEHEM STEEL COMPANY.

4″ KRUPPIZED BALLISTIC PLATE No. 22063B$_1$.

Order of firing.	Where and date tested.	Calibre of gun.	Armor piercing projectiles. Maker.	Capped or uncapped.	Wt.	Striking velocity.	Coefficient of De Marre.	Striking energy.	Thickness of plate.	Manuf'g No. of plate.	Penetration. Est'd.	Penetration. Act.	Cracks produced.	Effect on shell.	Remarks.
1	Indian Head, Feb. 14, 1902.	4″	Wheeler Sterling.	Uncapped.	33	1847	1.39	781.3	4″	22063B$_1$	2.2″	..	None.	Wreck.	Alexander III side armor.
2	"	"	"	"	33	1848	1.39	782.2	"	"	1½″	..	"	"	"
3	"	"	Midvale.	"	33	1845	1.39	779.6	"	"	1.2″	..	"	"	"

4½″ KRUPPIZED BALLISTIC PLATE No. 43676B$_3$.

1	Sandy Hook, Dec. 2, 1905.	5″	Midvale.	Capped.	58	1510	*1.197	917.8	4½″	43676B$_3$	..	.1″	None.	Wreck.	U. S. A. Gun Shield. <27771>
2	....	"	"	"	58	1535	*1.217	948.5	"	"	⅝″	..	"	"	"

6″ KRUPPIZED BALLISTIC PLATE No. 29876B$_1$.

1	Indian Head, July 8, 1902.	6″	Carpenter.	Uncapped.	100	1940	1.412	2612.2	6″	29876B$_1$	2.4″	..	None.	Wreck.	Pennsylvania side armor.
2	"	"	"	"	100	1901	1.404	2508.2	"	"	..	2.4″	"	"	"
3	"	"	"	"	100	1902	1.405	2510.8	"	"	2.4″	..	"	"	"

*Note:—Coefficients marked thus * can only be compared with other capped projectiles.

BETHLEHEM STEEL COMPANY.—CONTINUED.

6″ KRUPPIZED BALLISTIC PLATE No. 41347B$_3$.

Order of firing.	Where and date tested.	Calibre of gun.	Armor piercing projectiles.			Striking velocity.	Coefficient of De Marre.	Striking energy.	Thickness of plate.	Manuf'g No. of plate.	Penetration.		Cracks produced.	Effect on shell.	Remarks.
			Maker.	Capped or uncapped.	Wt.						Est'd.	Ac't.			
1	Indian Head, April 25, 1904.	6″	Wheeler Sterling.	Capped.	105	1681	*1.235	2059.3	6″	41347B$_3$	2¼″	..	None.	Wreck.	Louisiana lower casemate.
2	"	"	"	"	105	1647	*1.211	1976.8	"	"	..	1″	"	"	"
3	"	"	"	"	105	1672	*1.229	2037.3	"	"	..	1¾″	"	"	"

11″ KRUPPIZED BALLISTIC PLATE No. 24561B$_1$.

1	Indian Head, Mch. 7, 1902.	10″	Carpenter.	Uncapped.	500	1753	1.267	10664.4	11″	24561B$_1$	..	4.1″	None.	Wreck.	Maine turrets.
2	"	"	"	"	500	1779	1.286	10983.1	"	"	..	4.7″	"	"	"
3	"	"	"	"	500	1853	1.340	12609.9	"	"	..	5 5/16″	"	"	"

11″ KRUPPIZED BALLISTIC PLATE No. 46976B$_1$.

1	Indian Head, Jan. 25, 1905.	10″	Carpenter.	Capped.	510	1563	*1.146	8647.5	11″	46976B$_1$	4½″	..	None.	Wreck.	Connecticut side armor.
2	"	"	"	"	510	1623	*1.190	9324.2	"	"	4″	..	"	"	"
3	"	"	"	"	510	1649	*1.209	9625.3	"	"	4½″	..	"	"	"

*Note:—Coefficients marked thus * can only be compared with other capped projectiles.

TABLE OF ELEMENTS OF NAVAL GUNS (MODELS OF 1899), GIVING PERFORATION OF FACE-HARDENED ARMOR, SERVICE VELOCITIES AT RANGES UP TO 8000 YARDS, WITH SMOKELESS POWDER, CAPPED AND UNCAPPED ARMOR-PIERCING PROJECTILES, AT NORMAL IMPACT.

Caliber of Gun	Weight in tons	Length in caliber	Total length in inches	Total length of bore	Approximate charge of smokeless powder for maximum velocity	Weight of projectile	Muzzle velocity	Muzzle energy	Perforation at muzzle.				Remaining velocity at 1000 yds.	Perforation at 1000 yds.				Remaining velocity at 2000 yds.	Perforation at 2000 yds.				Remaining velocity at 3000 yds.	Perforation at 3000 yds.			
									Harvey nickel-steel		Krupp armor			Harvey nickel-steel		Krupp armor			Harvey nickel-steel		Krupp armor			Harvey nickel-steel		Krupp Armor	
									Projectiles		Projectiles			Projectiles		Projectiles			Projectiles		Projectiles			Projectiles		Projectiles	
									Capped	Uncapped	Capped	Uncapped		Capped	Uncapped	Capped	Uncapped		Capped	Uncapped	Capped	Uncapped		Capped	Uncapped	Capped	Uncapped
				Inches	*Lbs.*	*Lbs.*	*Ft-secs.*	*Ft-tons*																			
3-inch, Mark I....	.87	50	154.3	149.7	5.	13.	2800	709	4.4	3.6	4.4	3.6	2130	3.1	...	3.1	...	1620	...	...	...	...	...	...	...	...	...
4-inch, Mark VII..	2.56	50	204.5	200.	15.	32.	2900	1870	6.7	5.7	6.4	5.6	2380	5.3	4.4	5.2	4.4	1955	4.	3.4	4.	3.4	1605	3.2	...	3.2	...
5-inch, Mark V ...	4.4	50	255.	250.	27.	60.	2900	3508	8.6	7.5	8.4	6.6	2460	7.	6.	6.7	5.6	2085	5.7	4.7	5.5	4.7	1770	4.6	3.9	4.6	3.6
6-inch, Mark VI..	8.37	50	300.	298.74	46.	100.	2900	5338	10.9	9.3	10.9	7.3	2525	8.9	7.7	8.8	6.8	2185	7.4	6.4	7.2	6.	1895	6.2	5.3	5.9	5.2
7-inch, Mark I....	13.33	45	315.	307.	74.	165.	2900	9646	13.2	11.8	13.2	10.5	2580	11.4	10.1	11.4	8.9	2295	9.8	8.6	9.7	7.6	2040	8.5	7.4	8.3	6.5
8-inch, Mark V ...	18.	45	343.	335.	115.	250.	2800	13602	15.0	13.6	15.	12.1	2530	13.2	11.8	13.2	10.4	2290	11.7	10.4	11.7	9.1	2070	10.3	9.	10.3	7.9
10-inch, Mark III..	33.4	40	400.	339.	240.	500.	2800	27204	20.	18.6	20.	17.1	2585	18.3	16.7	18.3	15.	2390	16.5	15.	16.5	13.5	2210	15.	13.	15.	11.5
12-inch, Mark III..	52.	40	493.	480.1	385.	850.	2800	46246	25.	23.4	25.	21.7	2620	23.	21.4	23.	19.4	2450	21.2	19.6	21.2	17.9	2295	19.5	17.9	19.5	16.2

NOTE.- The figures in the table fairly represent the present relation between gun and armor, assuming that the projectile remains whole after perforation and carries an effective bursting charge. Though for velocities corresponding to ranges up to 1000 yds. the figures favor the armor somewhat.

NAVY DEPARTMENT,

BUREAU OF ORDNANCE,

August 20, 1901.

BETHLEHEM STEEL CO.
6IN KRUPP STEEL PLATE NO 41347 B3
REPRESENTING GROUP EE COURSE ARMOR FOR USS LOUISIANA
IMPACT 6 INCH GUN USED VELOCITY 1672 FT SEC
BETHLEHEM STEEL CO.

ACCEPTANCE TEST. 6-INCH PLATE.

BETHLEHEM STEEL CO.
11" Krupp
Steel Plate No. 24561 BI
Representing Group No 3 Target Armor For U.S.S. Maine
2 Impact. 10" Inch Gun Used. Velocity 1893 Ft Sec
BETHLEHEM STEEL CO.
Nos 1335 F.S.
Nos 1336 F.S.

ACCEPTANCE TEST. 11-INCH PLATE.

ACCEPTANCE TEST. 11-INCH PLATE.

CHAPTER XXXIII.

THE PROVING-GROUND.

Prepared by LIEUTENANT-COMMANDER JOSEPH STRAUSS,
U. S. Navy.

1. All guns, gun carriages, ammunition, armor, and new devices in naval ordnance are tested at the Proving-Ground before being accepted for the service.

2. The United States Naval Proving-Ground it situated at Indian Head, Md., and comprises a tract of land of nearly one thousand acres, on the left bank of the Potomac river, about twenty-five miles below Washington. There is a clear range over the water six and one-half miles long.

3. The proof of guns.—After a gun is completed it is sent to the Proving-Ground and fired five times, with pressures ranging up to one and one-quarter times the service working pressure it is designed to withstand. Thus, a gun which is to be habitually used with a maximum pressure of sixteen tons will be subjected to a final pressure during proof of not less than 20 tons per square inch. The proof velocities must also be correspondingly high, in order that the chase and muzzle may be tested for their ability to withstand high pressures. After proof the gun is stamped with the letter P and the initials of the officer in charge of the Proving-Ground, after which it is returned to the gun factory at Washington.

4. Every gun manufactured for the naval service is submitted to this proof; in the case of those guns manufactured by private concerns equipped with a proving-ground, the proof is conducted by the Inspector of Ordnance attached to the works.

5. Proof of powder.—An "index" of powder is, generally speaking, the largest lot of a single kind of powder that the capacity of the manufacturing plant is capable of blending. Blending houses are usually large enough to mix from 25,000

to 50,000 pounds, and these figures, therefore, represent the weight of one index. Small-arm and machine-gun powders are usually made up into indices of less weight.

6. After the index is boxed and ready for shipment, a sample of prescribed weight is sent to the Proving-Ground for proof. A careful chemical analysis of the sample is made at the laboratory in order to ascertain whether the stability, percentage of nitrogen, residual volatiles and solubility are in accordance with the specifications. The powder is then fired in the gun for which it is intended, beginning with small charges and working up to the required velocity, unless the proof is halted by the development of pressures in excess of those permissible. For a required velocity the weight of charge used must not exceed a given amount, nor must the pressure exceed that for which the gun is designed. After fixing the charge, a report of the ballistic and chemical qualities are forwarded to the Bureau of Ordnance, upon which the powder is either accepted or rejected. If accepted, an index number is assigned, and this, with the manufacturer's name, date of manufacture, weight of charge, and manufacturer's lot-number is stenciled on the boxes and the index is shipped to a magazine.

7. **Proof of shell.**—Two kinds of shell are at present purchased for the Navy; armor-piercing and common. The armor-piercing are all capped down to and including the 3-inch. The inspector at the factory selects one shell from every lot manufactured, and this is shipped for test. It is fired with a striking velocity (fixed by the Bureau of Ordnance) at an armor-plate which is set up at a distance of about 100 yards from the gun. The conditions for acceptance are, that it must completely perforate the plate, no fragment of it to remain in front of the plate.

8. *Common shell* are fired at nickel-steel plates* having a thickness of half the caliber of the shell, with just sufficient velocity to get through. They must completely perforate the plate with-

* All common shell are now fired at "hard-faced" plates of a thickness equal to half the caliber of the shell; and it is required that all shell (armor-piercing and common) shall completely penetrate the plates and be recovered in a condition for effective bursting.

out sustaining any fracture that will open up the shell cavity. After this test, the shell is loaded with fine-grained black powder and exploded in a suitable chamber. If the fragmentation is satisfactory, the lot is accepted.

9. Cartridge-cases.—One case out of every lot of 100 is proved by firing it six times with service pressures, after which it must be in perfect condition. It must enter and extract easily during and at the end of the proof.

10. Fuses.—Minor-caliber fuses are fired against a 3-16-inch plain steel plate and must not have more than a fixed per-cent of failures to a lot. Larger caliber fuses are fired against a ⅝-inch steel plate under similar specifications. Both fuses must withstand a drop from a height of 30 feet when inserted in blind shell, without arming.

11. Shell powder must be well incorporated, clean, and free from dust, and exhibit a proper glaze. It is tested in small-arms for velocity.

12. Armor.—Face-hardened armor is tested by firing armor-piercing projectiles against it with normal impact. The plate is always backed with 12 inches of oak backing secured to two ⅝-inch skin plates by armor bolts spaced at normal intervals. It is set up against the target structure at a distance of about 100 yards from the gun. The velocity of impact and caliber of shell are fixed with reference to the state of the art of armor manufacture, and the plate must be able to resist a given number of blows without developing through-cracks or permitting any shot to penetrate through the skin plates.*

13. *Protective-deck plates* are of nickel-steel and are set up so that the projectile strikes them at an angle of from 7 to 9 degrees from the tangent to their surface. The plate must not fracture under the single blow delivered.

*Armor plates are now classified under two heads, class "A" and class "B." Class "A" are Krupp plates of 6 inches thickness and above. Class "B" are Harvey plates from 6 inches to 3½ inches in thickness. The striking velocity is necessarily different for the two classes, Krupp armor being assumed to have a resisting power one-third greater than that of Harvey armor.

14. Ranging guns.—The powder charge is carefully ascertained a short time before the ranging is to be conducted, in order to eliminate any changes in velocity that may have occurred since the last proof of the powder. The gun is laid at an exact angle of elevation of 1° and trained on a fixed mark and fired.

15. *The fall of the shot* is plotted from observations, with the theodolite and plane table, made by observers stationed at various points down the range. This operation is repeated at 3°, 5°, 7° . . . 15°, and back again through the same angles. The height of tide is noted in order to reduce the height of gun above the water to zero.

16. *The barometer, temperature,* direction and force of wind are also recorded, although, if possible, the ranging is conducted in calm weather. After plotting all of the shots and reducing the range for each to a normal temperature and barometer, these ranges are plotted on section paper and a smooth curve drawn through the positions. This curve then forms the basis for the range-table.

17. *A drift curve* is also plotted from the position of the shots as plotted on a horizontal plane. The "jump" of the gun on modern carriages is inconsiderable or variable, and is measured by firing the projectile through a paper screen.

Instruments Used at the Proving Grounds.

18. Boulengé chronographs.—For velocity work, three Boulengé chronographs are used. A separate circuit and screen are provided for each instrument. The Boulengé chronograph is operated, briefly, in the following manner: Two electro-magnets are each provided with a separate circuit which are cut in turn by the passage of the projectile. The wires that are cut are placed 30 meters apart; when the first circuit is broken a metal rod is dropped from the first magnet and when the second is broken a weight drops from the other magnet, which releases a knife that springs out laterally and cuts a nick in the first rod which is still in the act of falling. Before firing, a datum point is secured by breaking both circuits at the same time with a

suitable key; the distance between the datum point and the second nick furnishes a measure of the elapsed time between cutting the first and second circuits. From this time the mean velocity of the shot is calculated, and for all practical purposes represents the remaining velocity at the middle point between screens. A correction which reduces this velocity to the muzzle of the gun is readily taken from the ballistic tables.

19. In order to insure the cutting of the circuits, each wire is arranged in the form of a screen, the mesh being continuous and parallel at a distance apart depending on the caliber of the shot. The triple screens are placed a few inches apart, the first of a set being exactly 30 meters from the first of the second set. The use of three chronographs permits the selection of the most probable result in case the results vary.

20. Schultz chronograph.—Besides the three Boulengé chronographs, a Schultz chronograph is used for time measurements where more exact results must be obtained, such as velocities of recoil and counter-recoil, or in any case where several consecutive intervals must be measured.

21. This instrument consists, essentially, of a nickel-plated cylinder revolving by means of a falling weight, and the rotation of which is controlled with more or less constancy by means of a fan which is in gear with the mechanism: a stylus is fastened to one prong of a tuning-fork and the tuning-fork kept in vibration by means of a small electro-magnet, much in the same manner as electric trembler bells are arranged. The breaking of an electric circuit is the means employed to mark successive intervals of the measurement, the break causing a spark to leap across from a point near the stylus on the tuning-fork to the metal cylinder, the latter having been coated lightly with lampblack just before the measurement is to be made. As the cylinder revolves and the tuning-fork vibrates, a wavy line is traced on the surface and each spark is marked on the line by a small bright dot whenever the current is broken.

22. The speed of vibration of the tuning-fork is nearly constant and equal to about 250 a second. The distance between two sparks in terms of the vibrations would then measure N.004 sec-

onds. By means of a magnifying glass and micrometer the wave-length may be divided quite accurately into 100 parts, thus permitting the determination of time intervals of $\frac{1}{25000}$ of a second.

23. For the ranging of guns it is necessary to employ the following instruments:

(1) *A gunner's quadrant,* which consists of a level which is hinged at one end, the other end sliding on an arc and provided with a tangent screw and vernier. The movable end is tilted up to the required angle and clamped and the quadrant is then placed on some part of the gun or carriage that is parallel with the axis of the bore. The gun is now elevated until the bubble in the level comes back to the center, and the gun is then at the elevation required.

(2) *Theodolites or plane-tables* for plotting the fall of shot as they strike the water.

(3) *A stop-clock* which measures tenths of seconds to record the approximate time of flight of the projectiles.

24. Pressure gauge.—The pressure gauge consists of a cylinder of steel closed at one end with a screw-plug and copper washer, and made strong enough to resist great collapsing pressure. Into this cylinder is loosely inserted a circular prism of copper, with its base resting against the closed end. Into the other end a solid piston of steel is inserted and just presses against the other base of the copper prism. This steel piston is not packed in any manner, but is made to fit the cylinder with great nicety. A cupped disc of thin copper is gently pressed into the open end of the cylinder and serves to prevent any gases from flowing through beyond the piston. These gauges are of two kinds: those which screw into the mushroom of the breech mechanism, called mushroom-gauges, and those which are dropped into the bottom of a cartridge-case before the powder-charge is put in, called cylinder-gauges. Before inserting the prism, its length is carefully measured by means of a micrometer caliper, and after the gun is fired it is again measured, the diminution of its length furnishing a measure of the pressure it has been subjected to.

25. *The area of the prism* is, for all guns down to the 6-pounder,

1/6-square-inch; for guns below that caliber, prisms having an area of 1-30 square inch are used, as the larger gauges would seriously alter the density of loading where the chamber is so small.

26. *For pressure measurements up to 9 tons,* copper prisms are made ½-inch in length. At the Naval Gun Factory, where they are made, sample prisms of that length are gradually shortened in a testing machine, and the pressure corresponding to a given shortening noted from time to time, from which data a table is constructed which is used with that lot of prisms at the Proving Ground. For pressure measurements *above 9 tons,* prisms that have already been subjected to that pressure are used.

NOTE.—By direction of the Navy Department, the following suggestions are made to officers who are assigned to special instruction and ordnance duty at the Proving-Ground, outlining their course of study:

Suggestions to Officers on Temporary Duty under Instruction at Naval Proving-Ground and Smokeless-Powder Factory.

AT PROVING-GROUND.

27. Fuses and primers.

(1) Study the sectional models of primers and fuses.

(2) Method of inserting primers and fuses.

(3) New luting substance and its use.

28. Projectiles.

(1) The form, the cap, and the manner of securing the latter in latest designs.

(2) Action in flight and against armor.

29. Powders.

(1) Ballistic curves of velocity and pressure.

(2) Methods of packing, weighing, loading, ignition, obtaining the velocity, and fixing the charge.

AT POWDER FACTORY.

30. (1) General inspection of works and methods; then to laboratory.

(2) Obtain in advance the index numbers of powders for future ships.

(3) Study these indexes from every point of view, chemically and ballistically.

(4) Note well the appearance of all kinds and makes of powders, good and bad, of which there are a great number and variety on hand; in fact, samples of every index in the service may be studied.

(5) Observe laboratory methods as to tests of powders.

(6) Make heat and litmus tests, performing every step personally.

(7) As a test of accuracy, samples of good, bad, and doubtful powders will be furnished without disclosing the identity of each.

NAVY DEPARTMENT,
Bureau of Ordnance, December 28, 1904.

CHAPTER XXXIV.

NAVAL RANGE-FINDERS.

1. General.—(1) The trajectories of guns being more or less curved, it is necessary to know the distance of the target in order to adjust the line of sight, with respect to the trajectory, (i. e., to set the sight), so that the projectile on its descending branch will hit the point of aim.

(2) *The curvature of the trajectory* and the angle of fall increase as the range increases; hence, when the range is great, accurate range-finding is more necessary than when the target is close to the gun. It will be shown that this is just where all our range-finding methods are at fault. It is easy to get the range when the target is near, and inaccuracies in measuring are not serious; but these inaccuracies increase enormously with the range just where we would have them decrease.

(3) *Very high-velocity guns*, with their consequently flatter trajectories, give a smaller angle of fall and a greater danger space. For this reason, larger errors in sight-setting are permissible and the fire from such guns should be more accurate; this superiority of high-velocity guns is of even greater value in battle than their superiority in penetrating power as compared with low-velocity guns.

2. (1) **The danger-space** of a gun firing at a target of a certain height, is, for any particular range an interval of space between the point of fall and the gun, such that the target if situated at any point within the space, will be hit. For the same target and range, a gun with a flat trajectory will have a longer danger-space than will one with a high-curved path, as shown in the figures.

(2) The danger-spaces of a 50-caliber 6-inch gun, firing at a 30-ft. target, are given below. It is to be kept in mind that this is an exceptionally high-velocity gun, and that guns of older design have much shorter danger-spaces.

Range.		Danger-Space.	
1000	yards	1000	yards.
2000	"	759	"
3000	"	381	"
4000	"	222	"
5000	"	141	"
6000	"	94	"
7000	"	65	"
8000	"	46	"

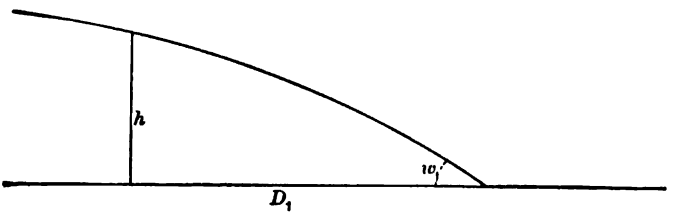


FIG. 1. ART. 2.

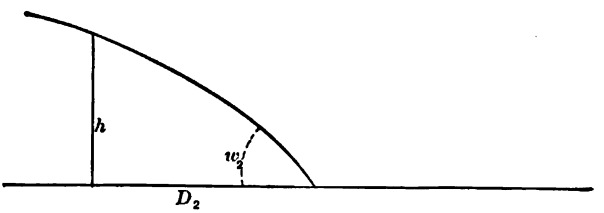


FIG. 2. ART. 2.

(3) Granting that the gun-pointer can fire with his sight exactly on the center of the target, this shows that the range at 6000 yards must be measured within 47 yards in order to hit the 30-ft. target. There is no known method of range-finding that can be relied upon to give such results; this fact alone demonstrates the extreme difficulty of making hits at these long ranges.

3. Eye-estimation of range.—(1) From the introduction of heavy guns on ship-board up to a comparatively recent day, the guns were so low-powered and inaccurate that they were effective only at very short ranges, and no very reliable range-finding

method was necessary. Even after sights were fitted to guns, there was at first no way of setting them; they merely gave a line parallel to the bore, and the allowance for the range was made by the gun-captain, perhaps by pointing at some portion of the rigging.

(2) A little later it became the custom to set the rear-sight-bar for the range by direction of the gun-captain, or of the division officer, who merely estimated the distance by his eye. Some did it, by depending upon the quality of the so-called "nautical eye"; others had rules of their own, based upon the distinctness with which they saw various objects on the decks of the enemy. The ranges being very short such methods answered; now, however, the battle-ranges are long, probably not less than 3000 yards, and greater accuracy is required. The theory of "eye-estimation" is no longer tenable and the stories of individuals who can estimate long ranges "within a few yards" are absurd.

(3) Experiments have shown that it is quite impossible to estimate ranges above 2000 yards with anything like sufficient accuracy. There are various aids, such as holding a finger in front of one eye, at arm's length, and noting the amount by which it moves across the target when held stationary and viewed with the other eye. While such methods are more accurate than simple estimation, none are up to the requirements of modern gunnery. It was found experimentally that changes in the atmospheric conditions and the intensity of the light, resulted in large variations in the estimates; the wildest guesses were made by "practised" observers as to the relative distances of dissimilar objects which were really abreast of each other; after considerable practice, fairly close estimates were made as to the distance of a certain ship, to which the observer had become accustomed, only to have them all thrown out when the ship turned at any other angle than broadside to. On a dark night, the estimates of the distance of a single point of light will often be several hundred per-cent in error. Eye-estimation, then, is not at all to be depended upon, particularly when made by the gun-pointer through a smoke-obscured gun-port.

The Telemeter.

4. (1) A method once proposed and thought well of for a time, depends upon the velocity of sound, the range being obtained by measuring the time between the flash of one of the enemy's guns and the instant its report is heard by the observer. The Boulengé Telemeter is a simple instrument for measuring this interval; it depends upon the velocity with which a plunger falls through the liquid in a glass tube when the instrument is turned upright.

(2) It is clear that this method could not possibly be of any use in a modern action. A more promising method, but one not capable of practical use, would be to time the flight of a projectile, if its point of fall could be determined, and read the range from a prepared table with the time of flight as the argument. Granting that the time of flight could be accurately measured, the correct distance would be given only by a shot which hits the target; in this case the *sight-bar range* can be found by simply taking the reading of the firing gun's sight-bar; this is more valuable information than the exact distance and would be obtained directly.

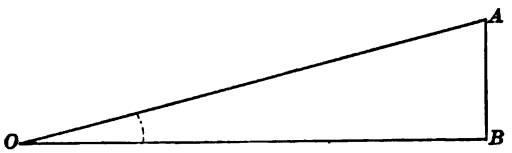


FIG 3. ART. 5.

Mast-head Heights.

5. (1) If the height AB of a mast-head or smoke-pipe of the enemy's ship above the water-line be known, the angle subtended by this height may be measured and the resulting right triangle solved for OB, the actual range. To give quick results, a table of ranges for various heights and observed angles may be prepared and the range given as soon as the angle is read.

(2) **The stadimeter,** an invention by Lieutenant (now Commander) B. A. Fiske, U. S. Navy, solves this triangle graphically and gives direct readings. The instrument was not designed for *long ranges* and is not useful for modern gunnery. It is, how-

ever, in constant daily use for measuring the distances of ships of the fleet during maneuvers. Unless the water-line is distinctly seen, the method will have grave errors, and it will be an easy matter for the enemy to alter his mast-head heights at the beginning of war. The method cannot be used at night, and under the best conditions, at battle-ranges, the angle subtended by even a very lofty mast must be measured with an extreme of accuracy which no instrument can be relied upon to give.

Buckner's Method.

6. Buckner's method was originated by Lieut. W. P. Buckner, U. S. N., and has given good results during long use. The

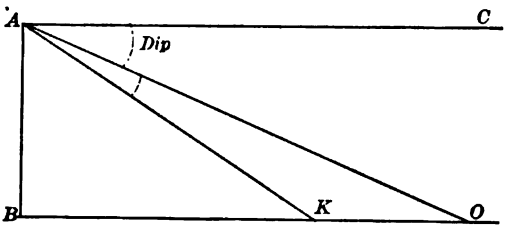


FIG. 4. ART. 6.

observer is stationed at a certain known height, which should be as great as possible above his own water-line, from which point he measures with a sextant the angle between the horizon and the target's water-line. In the figure, A is the observer, B his water-line, and K that of the target; the height AB is known. Now regard O as the horizon of A and, disregarding the earth's curvature, consider that the distance BO is in a straight line and that AC is parallel to it. The angle CAO is the dip from A, and its value has been tabulated for different heights. Now if the angle KOA is measured, we know the angle $KAB = 90° - (\text{Dip} + KAO)$. Thus in the right-triangle ABK we know AB and KAB and may compute BK, the required range. In practice, the observer is provided with a table from which he reads the range as soon as he gets the sextant angle; the greater the value of AB, the less will be the error caused by errors in observation.

Obviously, a clear horizon is essential and the method cannot be extended to use at night. Also, in rough water the target's water-line cannot be distinctly seen and AB varies as the observer's ship rises and falls or rolls to the sea. Granting perfect conditions, the limitations are made evident by the fact that at 2500 yards, with an observer's height of 100 feet, an error of two minutes of arc in observing, gives an error in range of over 100 yards; hence the method is inadequate for modern gunnery, even under the most favorable conditions. There are range-finding instruments which, depending upon this principle, give direct readings; such is the Searle and Saegmuller. Beyond convenience in observing, they appear to have no advantages.

Methods with Horizontal Base-Lines.

7. The methods given thus far depend upon a vertical base-line; it now remains to consider those that have horizontal bases. The sea-coast artillery system of position-finding is on this principle. Within limits, a very long base-line can be utilized, with observers at each end connected by reliable electrical communications. The base-line is not perpendicular to the line of fire and a rather complicated system results. However, from the nature of the work, the instruments and communications are permanent and can be made accurate and reliable. The actual observation of the target is simple and the system gives satisfaction.

8. Similar systems, notably that of Lieut. Fiske, have been used on ship-board, in spite of the fact that the longest obtainable base line is all too short. Only a measure of success resulted in practical service, although the systems are theoretically correct and gave accurate results under favorable conditions. The instruments are delicate and difficult to install and were, with their electrical connections, too much affected by service usage and the shocks of gun-fire. Thus, the question has narrowed to self-contained direct-reading instruments (to be handled by single observers), which necessarily have extremely short base-lines kept perpendicular to the line of fire while taking the observation.

9. The Zeiss range-finder is generally built as a portable instrument; it takes advantage of one's ability to see stereoscopically,

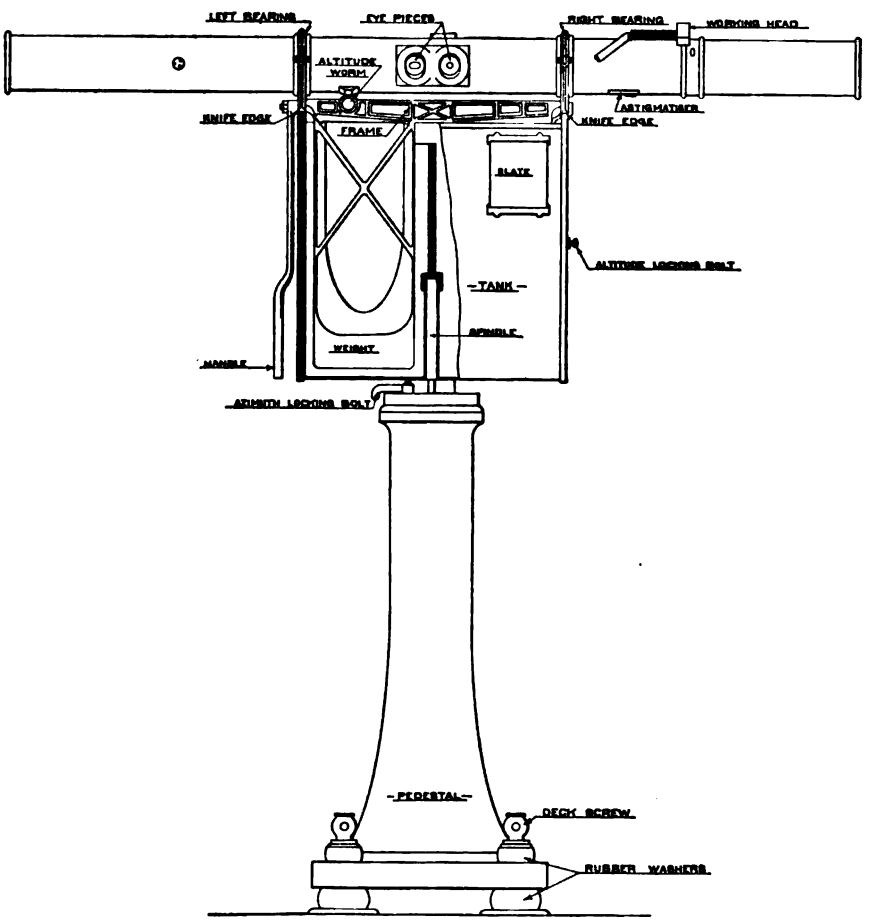
utilizing the telescope to extend this power. It has advantages for use on shore, particularly for controlling infantry fire, but has not shown its suitability for naval gunnery; extensive training would seem to be required in the observer.

Barr and Stroud Range-Finder.

10. The Barr and Stroud range-finder (Plates I and II), has been adopted by the U. S. Navy, as well as by Great Britain, Austria, and Japan, and is for naval purposes the most satisfactory of any yet devised. Plate I shows a profile of the instrument and its mounting. In Plate II, Figs. 1, 2, and 3 are diagrammatic representations of the instrument, details of construction being omitted for the sake of clearness in the explanation of the principle of operation. Figs. 4, 5, and 6 are front, rear, and end views of the outside.

11. (1) **The principle of the instrument** depends upon the diverging angle at which the rays of light come from the target to the reflectors. The distance between the reflectors is the base-line, and instruments with long bases are more accurate than those with short ones; the usual size has a base-length of 4½ feet. Two beams of light from the target are received by the reflectors and transmitted through the objectives towards the center of the frame, where an arrangement of prisms is placed to reflect the rays outward through the *right* eye-piece. In this way, two partial images of a distant object are seen, one over the other, as shown in Fig. 9, the image seen in the upper half of the field of view being formed by the equivalent of a telescope directed towards the target from the right-hand end of the instrument; and the image seen in the lower half being formed by the equivalent of a second telescope directed toward the target from the left-hand end. The images are separated by a thin black line, as shown in Figs. 8 and 9; this line is called the separating line.

(2) Suppose a very distant object is viewed by rays as shown by L_1 L_2 (Fig. 2) and that the partial images of that object are seen in correct coincidence as illustrated by Fig. 8. If now the object approaches the instrument along the line L_1, the beam of light received by the right-hand reflector will take a different direc-



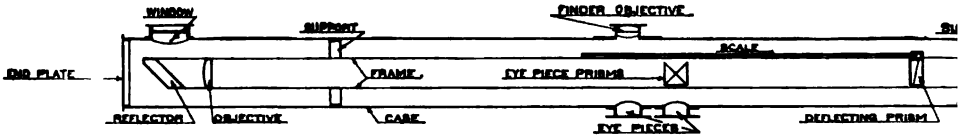
BARR AND STROUD RANGE-FINDER (PROFILE).

tion, as shown by the line L_2, and the partial images will no longer appear in proper coincidence, but will occupy such relative positions as are shown by Fig. 9. (The relative position of the images is not affected by any turning of the instrument in azimuth; the images move together across the field.) The partial images might be brought together by rotating one of the reflectors, but the necessary movement would be almost infinitesimal, and would consequently require to be made and indicated with excessive delicacy. A different method is employed.

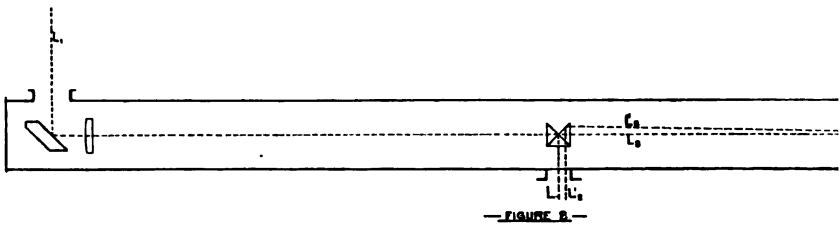
(3) In this range-finder, the images are brought into coincidence by means of a "deflecting prism" of small angle (Fig. 1), which is placed in the path of the rays from the right-hand reflector and is movable along the tube. The action of the prism in producing coincidence is illustrated in Fig. 3. The partial images of a very distant object are in coincidence when the prism is in position N, but it has to be moved to the position O in order to bring the images of a near object into coincidence. As usually constructed, a motion of the prism of about six inches corresponds to a change in range from infinity to about 250 yards.

(4) An ivory scale is attached to the reflecting prism and on it the distance of the object viewed is read by means of a scale-lens in the left eye-piece; the scale is graduated to give the ranges in yards. It should be particularly noted that since the scale is attached to and moved with the deflecting prism, any slackness or defect in the gear by which the scale is moved produces no error in the reading; therefore no amount of wear can affect the accuracy of the instrument.

12. The construction.—Externally, the range-finder is a tubular case about five feet long and 3½ inches in diameter; this case carries the eye-pieces, finder, objective, and the protecting windows. The other optical parts, upon which the accuracy mainly depends, are fixed to an inner case (see Fig. 1), which is supported from the outer case from only two points. This construction makes the instrument remarkably unsusceptible to hard usage, shocks of gun-fire and temperature changes. The deflecting prism, with its attached scale, is translated by a screw-shaft which is actuated by the working head, placed on top convenient



— FIGURE 1 —



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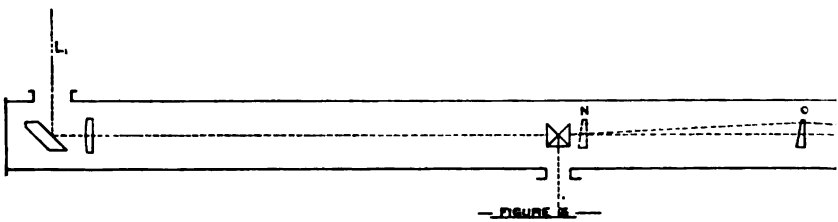
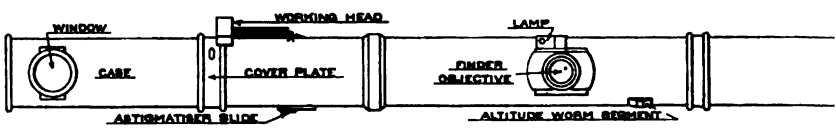


— FIGURE 3 —



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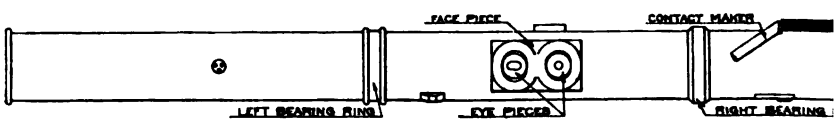

— FIGURE 5 —

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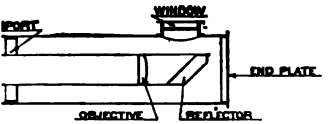
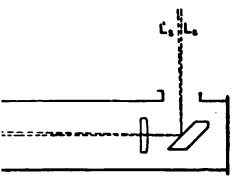
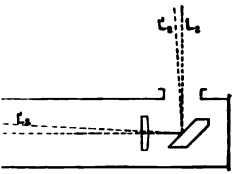
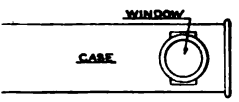
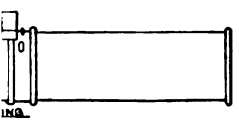
DETAILS OF

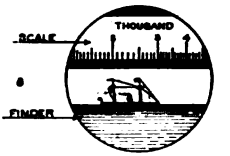




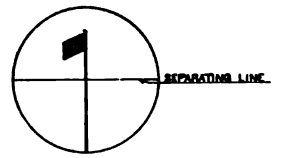




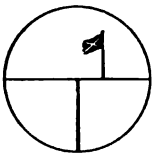




LEFT EYE FIELD.
FIGURE 7.

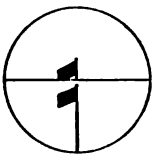


RIGHT EYE FIELD.
FIGURE 8.

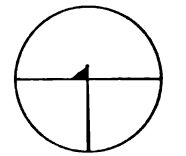


IMAGES NOT IN COINCIDENCE.
FIGURE 9.

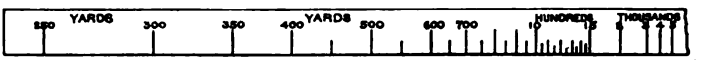
ASTIGMATISED LIGHT.
FIGURE 10.



DUPLICATION.
FIGURE 11.



DEFICIENCY.
FIGURE 12.



SCALE—NOT FULLY DIVIDED.
FIGURE 13.

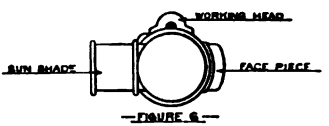


FIGURE 6.

UD RANGE-FINDER
CONSTRUCTION.

to the observer's right hand. The scale is divided in hundreds up to 5000 yards and then to thousands up to 10,000 yards. The eye-pieces are fitted with a rubber buffer for the observer to rest his forehead upon, thus steadying his eyes, cutting out external light, etc. The distance between the eye-pieces is adjustable to suit the breadth between the eyes of different observers.

13. The "finder" is to facilitate finding the target; it forms, with the left eye-piece, a low-powered telescope of large field. The upper portion is obscured by the scale, also to be read by the left eye; the field of the right eye-piece is taken up, as before explained, by the two images. For night observations, a low-powered electric lamp is fitted near the finder-objective (see Fig. 4). It shines through the ivory scale with light enough to make the graduations legible. The lamp is turned on or off by the "contact-maker" (Fig. 5).

14. Adjustments.—(1) It is found that the instrument seldom needs adjusting unless it meets with an accident. Two adjustments are provided for, both of which are made by small milled heads that are ordinarily covered by a ring near the right-hand end.

(2) *The adjustment for halving* is to cause the lenses to be in such positions that the partial images will form a complete representation of the target; there must be neither "duplication" (see Fig. 11), nor "deficiency" (see Fig. 12), in which a part of the target does not appear in either upper or lower image. This adjustment can be tested on any object over 250 yards distant; distance need not be known, and something of irregular form and little height is most suitable.

(3) *The "coincidence" adjustment* corresponds to the index correction of a sextant; on its perfection depends the accuracy of the instrument in measuring ranges. It is conveniently tested, or made, by observing the moon, when bright and clear, or the sun when it is low down and not too bright for the naked eye. Set the instrument at "infinity" by the scale and note if the edges of the luminary are in coincidence; if not, turn the milled head until they are. The adjustment is also readily made by observing a clear-cut object at a known distance which must be

at least 800 yards. This adjustment should be very carefully made and all the error taken out, for any residual error *increases as the square of the range.* For this reason it is inconvenient, at least, to have an index correction as with a sextant.

15. The mounting.—It will at once be noticed that the mounting does not enable the observer to keep the axis of the instrument horizontal; this is not necessary, because the effect of any inclination, such as that caused by the heel of the ship, merely makes the object appear inclined as regards the separating line. It is possible for the observer to keep the objectives on the target under the most unfavorable conditions and the mounting is cleverly designed with this requirement in view. The outer case is mounted in bearing rings (see Plate II), and is rotated by the handle, in the left hand. The first instruments, and the one here shown, were also connected to a heavy weight which was designed to swing in water in the tank and act as a pendulum to keep the instrument level, thus assisting the observer's left hand; the water was to damp the swing of the pendulum. This feature does not appear in the later instruments, and the observer has to do all the leveling himself; with but a little practice this is rather easier than to keep a telescope pointed. The observer rests his breast against a support on the frame and rotates the entire upper part of the mounting on its pedestal to keep the target in the field. It has been proved by trial that the instrument will give fair results when there is so much motion on the ship as to make accurate gun-pointing out of the question. There should be several range-finders on each ship, because all-round views can rarely be given for its mounting.

16. Uses in navigation.—The Barr and Stroud range-finder lends itself readily to use in navigation. The distance of a point of land in daylight or that of a light at night is given with one observation, in a few seconds. It can be used to determine the turning-circle of a ship by steaming around a pole floating upright; the speed of a ship can also be gotten, for a short distance, with an accuracy of at least one per-cent, and the effect of current is eliminated if the pole is floating at about the same depth as the ship. It is said that by using the astigmatiser the points of

light shown by a torpedo craft under the search-light can be drawn out into streaks that are plain enough to permit a fairly reliable observation for range. In this particular instance, there is certainly no other method that is applicable, and eye-estimation under the conditions is merely the wildest guess-work. The standard of accuracy is rather higher than any other method, now known, will give. At 3000 yards, the average errors are less than 0.5 per-cent. At the long ranges, the errors are less than those of the gun with its ammunition.

17. Sight-bar range.—Thus far, only the range or actual distance of the target has been considered while the range that the officer charged with the control of the fire is called upon to give to his sight-setters is the *sight-bar-range*. For the same actual range this sight-bar-range will vary for the different calibers of the battery, for the different indices of powder for the same calibers, and even for the same index when fired under varying conditions of the atmosphere and temperature. If a few of the variants give accumulative errors, the sight-bar-range may differ hundreds of yards from the actual range. Most dependence is likely to be given to watching the trajectory and point of fall of the projectiles, estimating the amount by which they miss the target. It is then not essential that the actual distance be known, if the sights can be changed by increments such that the mean point of impact is brought on the target. This science of fire control, really sight-bar-range-finding, is about the most important and the most difficult branch of the profession; our experiments and systems are confidential. Suffice it to say that any range-finding instrument, however accurate and reliable at long ranges, can be no more than an aid to fire-control, and only a part of the problem is solved when the actual distance of the target is known.

CHAPTER XXXV.

SUBMARINE MINES.

NOTE.—Much of the information in this chapter was taken from Bucknill's "Submarine Mines and Torpedoes," and from Armstrong's "Torpedoes and Torpedo Vessels."

1. Definition.—A submarine mine may be defined as a charge of explosive confined in a strong case moored beneath the surface of the water in rivers, channels, and sometimes in outer roadsteads for the purpose of preventing or delaying the passage of hostile ships. The charge need not necessarily be so powerful as to completely shatter a ship, but its explosive effect should be sufficient to blow a hole in a double bottom and sink any ship that strikes, or passes near, the mine.

2. Mines are of several different classes. Each class has its peculiar uses, and the class to be used and the weight of the charge to be employed, depend upon the time and facilities available, the depth of water, the rise and fall of the tide, the strength of the current, and other conditions that may exist at the port to be defended.

3. History and development.—Submarine mines were first used with effect by the Confederates during the Civil War, 1861-1865, and, notwithstanding the crude and imperfect appliances at that time, and the use of gunpowder, which was often rendered harmless by the leakage of mine cases, more than thirty ships were destroyed or seriously damaged by these mines.

4. Noting this fact, European nations took up the subject and began extensive experiments which have resulted in a steady development and improvement of submarine mines. This auxiliary method of harbor defense is now of great importance.

5. General Abbot's experiments.—General Abbot, Corps of Engineers, U. S. Army, contributed greatly to the knowledge regarding submarine explosions, and his report to Congress giving

the results of his exhaustive experiments at Willets Point is regarded as a classic.

6. The Oberon experiments.—In England, an important series of experiments was conducted by exploding mines of different sizes, and at various distances, against the hull of H. M. S. Oberon, a large number of crusher gauges being used to record the pressure of each explosion in order to discover a law connecting the pressure with the weight of the charge and the distance of the latter from the ship.

7. As a result of the Oberon and other experiments, various opinions have been advanced as to the pressure necessary to destroy or blow a hole through the double bottom of a modern ship. Some authorities put this pressure as low as 6000 pounds per square inch; but Colonel Bucknill, who was a member of the "Committee on the Experiments against H. M. S. Oberon," expressed the opinion that the pressure required is nearer 12,000 pounds per square inch. Considering the increased strength of modern ships, Colonel Bucknill's rule would be the safer one to adopt.

8. Explosives for mines.—High explosives have replaced gunpowder, and are now exclusively used for submarine mines. Their explosive action is not seriously affected by moisture, leakage of the mine case is not so liable to render them ineffective, and they are from four to six times as powerful as gunpowder.

Gun-cotton and explosive gelatine are preferred, and the former, being extensively employed for military purposes, is more generally used for submarine mines, though it is not quite so powerful as gelatine.

9. Destructive radius.—As a result of a careful study of submarine experiments, several formulæ have been proposed to determine the distances at which different charges of the various explosives would be effective against a double bottom. It is evident that such a formula can only be approximately correct; but an approximate rule may be useful. Assuming that a pressure of 12,000 pounds per square inch will be fatal against a modern ship's bottom, the following rule may be used to obtain the distances at which mines containing gun-cotton should be effective:

(1) For distances between 20 and 50 feet from the ship's bot-

tom, multiply the distance in feet by 12 to get the effective charge in pounds; for distances less than 20 feet, multiply by 8. Thus at 30 feet, 360 pounds, and at 10 feet, 80 pounds of gun-cotton would be effective against a double bottom. Or, given the weight of the charge in pounds, to find the distance at which it will be effective, divide the weight by 12. Thus, 480 pounds would be effective at about 40 feet.

(2) It is recorded that in an experiment conducted by Danish naval officers, 660 pounds of gunpowder, exploded at a distance of 24 feet, tore a hole 100 feet square in the outer bottom of a ship and sank the ship. Assuming gun-cotton to be about four times as powerful as gunpowder, 170 pounds of the former would have produced the same result. The rule stated above would give between 200 and 300 pounds of gun-cotton for a distance of 24 feet, and it would appear, therefore, that the rule gives an ample charge.

10. Classes of mines.—Submarine mines are of two general classes:

(1) Buoyant mines.

(2) Ground mines.

Buoyant mines are moored to the bottom so that they may be held above their anchors a certain distance beneath the surface of the water. Ground mines rest directly upon the bottom, where they should be securely anchored.

Buoyant Mines.

11. There are several kinds of buoyant mines, as follows:

(1) Contact mines.

(2) Electro-mechanical mines.

(3) Electro-contact mines.

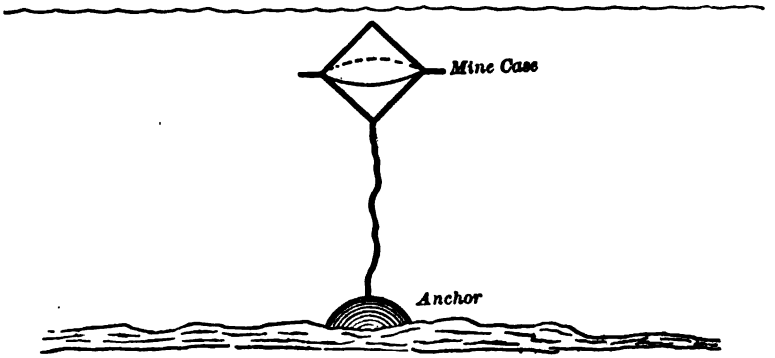
(4) Observation mines.

12. The different kinds of buoyant mines will be briefly described in the order named, which is the inverse order of their safety and effectiveness.

13. Contact mines.—The contact mine is the simplest and crudest form of submarine mine. It consists of a strong watertight case containing the charge, moored at a certain depth below

the surface of the water, the case having a number of projecting levers or firing-pins, which, if struck by a passing vessel, may be driven in, thus exploding the charge by direct percussion and in immediate contact with the vessel's bottom. Such were the mines used by the Confederates during the Civil War.

14. *It is evident that contact mines are dangerous alike to friend and foe,* and should only be used, therefore, where other and safer forms are not available. The firing-pins, or levers, have often been rendered ineffective by the adhesion of barnacles, or by other causes, as was the case with the Spanish mines at



CONTACT MINE. ART. 13.

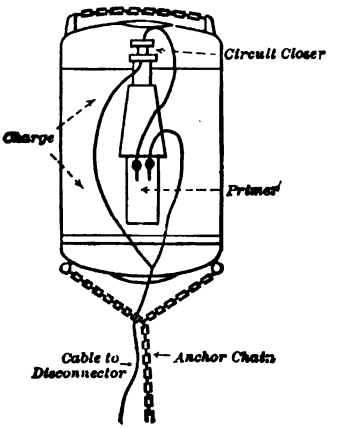
Guantanamo. Leakage may destroy a percussion-primer and thus prevent explosion, even when the firing-pin is driven in.

15. Electro-mechanical mines.—The electro-mechanical mine is a modification of the ordinary contact mine in which, instead of firing the charge by a percussion-primer, the firing-pin (or any other form of circuit-closer) completes the circuit of a firing-battery carried within the mine-case. This form may be rendered somewhat safer in handling, and more certain of action, than the percussion form of contact mine, but when once moored it is equally objectionable in that it is under no control from the shore.

16. Electro-contact mines.—The electro-contact mine differs from the electro-mechanical mine only in having the firing-battery on shore instead of at the mine. This brings the mine under con-

trol from the shore and removes one of the great objections to contact mines. When hostile ships are not in the vicinity, the firing-circuit may be broken at the shore station so that an accidental blow will not fire the mines, and a friendly ship may pass in safety. When the enemy appears, the firing-circuit may be closed at the shore station and the mines will then be operative upon contact.

17. Laying electro-contact mines.—To reduce the number of firing-batteries and electric cables as much as possible, electro-



ELECTRO-CONTACT MINE. ART. 16.

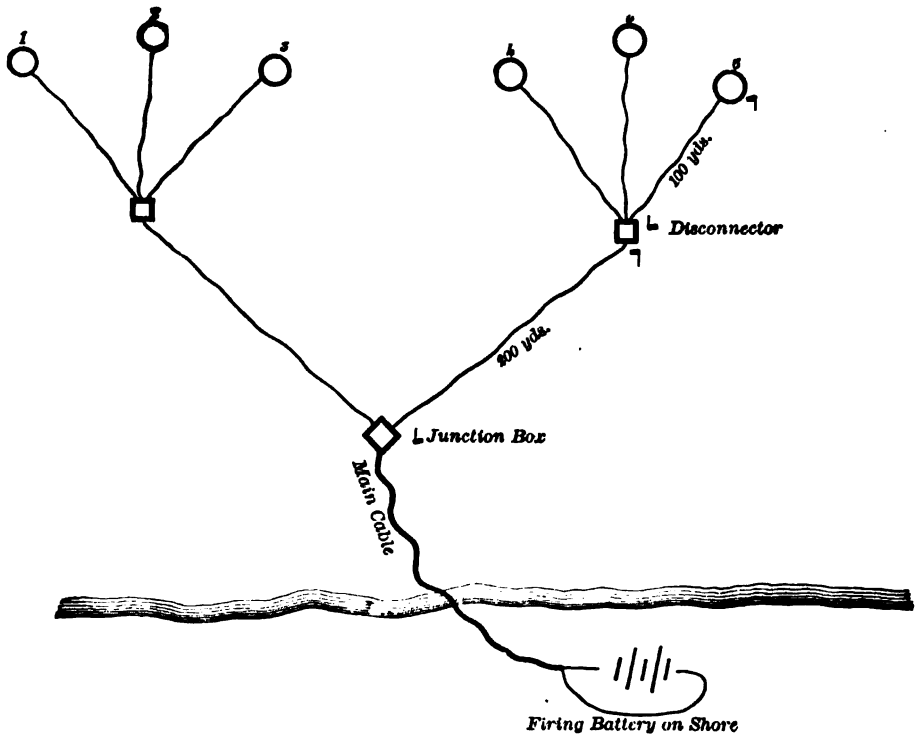
contact mines should be laid in groups of three or more, as shown in the sketch.

18. Three or more mines may be joined by electric cables to a *disconnector box* 100 yards distant, and two or more disconnector boxes may be joined by 200-yard lengths to a common *junction box,* the main or group cable leading from the junction box to the firing-battery in the station on shore. By means of the disconnector a mine which has been fired or destroyed may be cut out.

19. Anchors.—Mushroom anchors are preferred for all kinds of submarine mines.

20 Firing electro-contact and electro-mechanical mines.—Instead of using projecting levers or firing-pins to fire electro-

contact and electro-mechanical mines, the firing-circuit may be closed at the mine by a rolling ball, or by mercury contained in a cylinder. When the mine is tilted through a certain angle, or is struck with sufficient force, the ball or the mercury will rise in



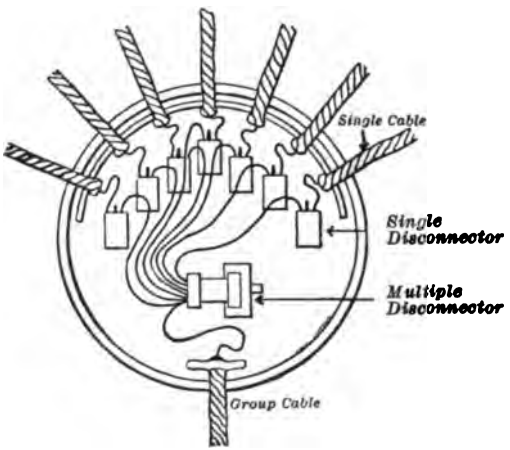
GROUPS OF CONTACT MINES. ART. 17.

the cylinder, complete the circuit and fire the mine. This form of circuit-closer renders electro-mechanical and electro-contact mines much more certain of operation, because there are fewer holes in the mine-case and less chance of leakage than with projecting firing-pins or levers; and rust or the adhesion of barnacles will not cause failure.

21. Contact buoys.—Instead of placing both the explosive charge and the circuit-closer in a single case, it is usual and pre-

ferable in all forms of electrical mines to place the circuit-closer and firing mechanism in a separate buoy called a "contact buoy" which is connected with the mine case and is held a few feet above the latter, and at the desired distance below the surface of the water, as shown in the sketch.

22. The use of a contact buoy permits a smaller and lighter case for the explosive charge. In electro-contact and electro-mechanical mines a blow upon the contact buoy closes the firing-



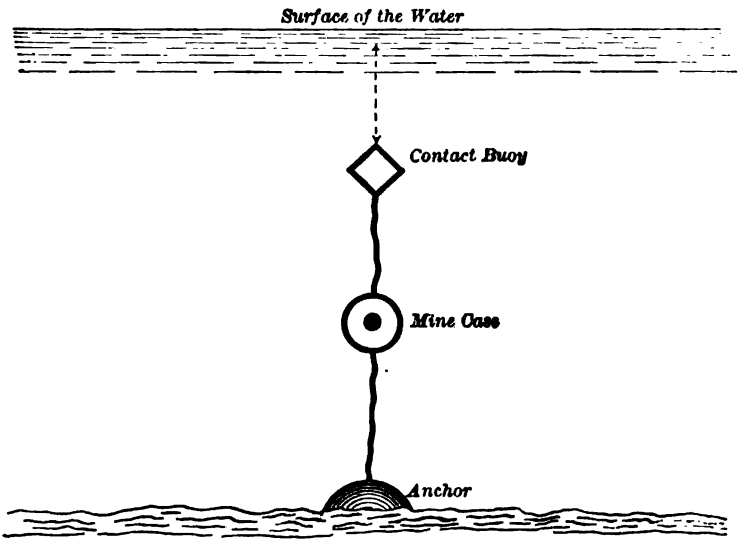
JUNCTION BOX. ART. 18.

circuit, and the current passes down an electric cable through the primer of the mine and explodes the latter.

23. Observation mines.—Observation mines are so called because each mine may be regarded as an observer which signals to the shore when its contact buoy is struck, and because such mines are completely under the control of an operator or observer at the firing-station. This is the standard form of buoyant mine used by all nations for permanent harbor defenses.

24. Each mine is moored, with its contact buoy above it, in the same general manner as electro-contact mines. But with observation mines there are usually two distinct electric circuits—the signaling-circuit and the firing-circuit. When the contact buoy

is struck, or sufficiently tilted, the circuit-closer in the buoy closes the signaling-circuit, which rings a bell, lights an electric light, or causes a shutter to drop over a keyboard in a firing-station on shore. The operator may then touch the corresponding key beneath the signal, thus closing the *firing-circuit* and exploding the mine. It is not necessary that the operator shall see the enemy. The firing-station may be underground, quite safe from

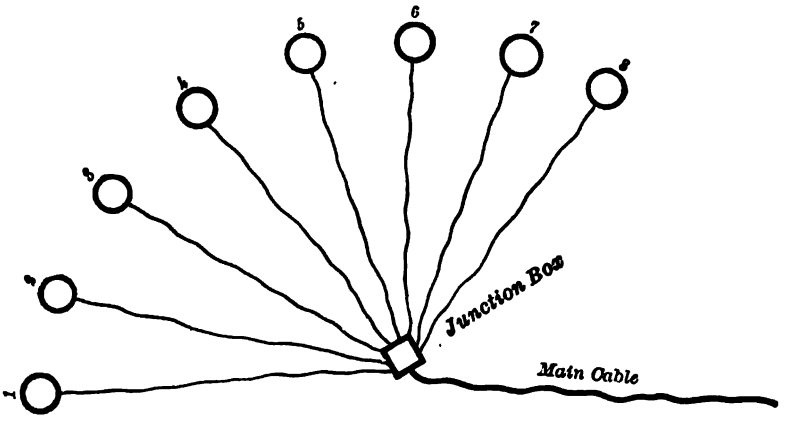


MINE WITH CONTACT BUOY. ART. 21.

hostile fire. Thus an enemy striking the contact buoy of an observation mine may signal his own destruction.

25. Groups of observation mines.—Observation mines are usually moored in groups of about seven. Each mine has its own anchor, mine-case, and contact buoy. The electric cable for each mine passes from the circuit-closer in the contact buoy down through the mine-case, then to the anchor and along the bottom to the junction box of the group, from which the main cable leads to one key of the firing-station on shore. Disconnector boxes might be interposed between the mines and the junction boxes, as in the case of electro-contact mines.

26. Firing.—It is evident that arrangements may be made by which all the mines of a group may be fired simultaneously, or the explosion may be limited to the mine whose contact buoy has been struck. The size of the mines and the general system of laying them will determine whether all or only one mine of a group should be fired. When the mines are large, for instance, only one mine of a group may be expended at a time; if small mines are used, a whole group may be fired simultaneously to insure the destruction of a ship. Some nations use very heavy charges—500 pounds of gun-cotton—in observation mines.

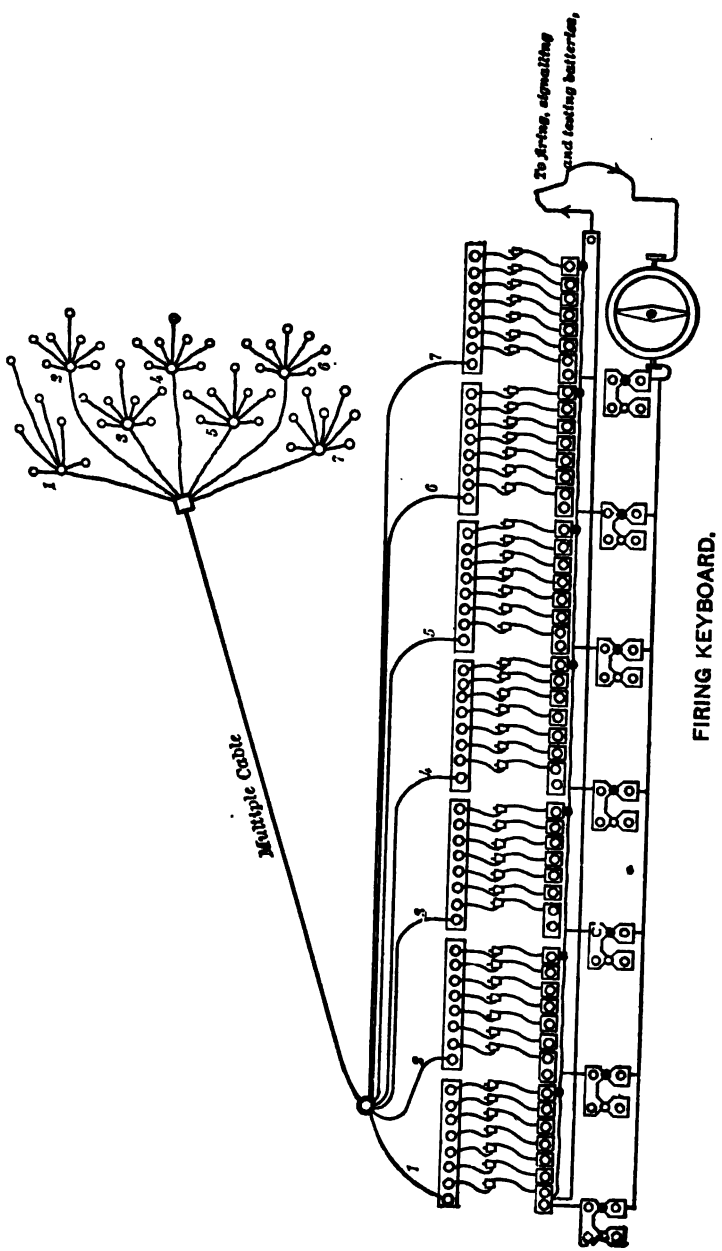


GROUP OF OBSERVATION MINES. ART. 25.

27. The firing keyboard.—Plate I will give an idea of the arrangement of a firing keyboard. It is not drawn to scale, but the lead of the cables and the connections are shown for seven groups of mines.

28. Automatic firing.—It is possible, in the absence of the operator, or at any time if thought desirable, to so arrange that the shutter which drops by the closing of the signaling circuit when the contact buoy of a mine is struck, may fall upon the firing-key and close the firing-circuit at the station, thus firing the corresponding mine, or group of mines, automatically.

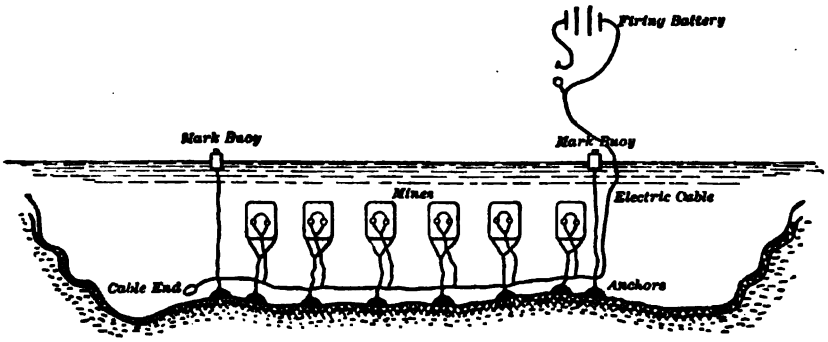
29. Judgment firing.—The firing-station may not be under-



FIRING KEYBOARD.

ground, in which case the operator may be so stationed at some convenient point that he may command a good view of the mine field. By the aid of ranges, buoys, etc., he may determine when a ship is in the proper position, and fire a mine or group of mines without the aid of contact buoys or a signaling-circuit. This is called "judgment firing." It is evident that it might fail at night, or under some conditions of weather, etc. The operator is liable to error. But this plan may be resorted to when other facilities are not available.

30. Lines of mines.—A narrow channel may be defended by a simple system of several lines of mines, each line of six or more mines being on one cable.



LINE OF MINES ON ONE CABLE. ART. 30.

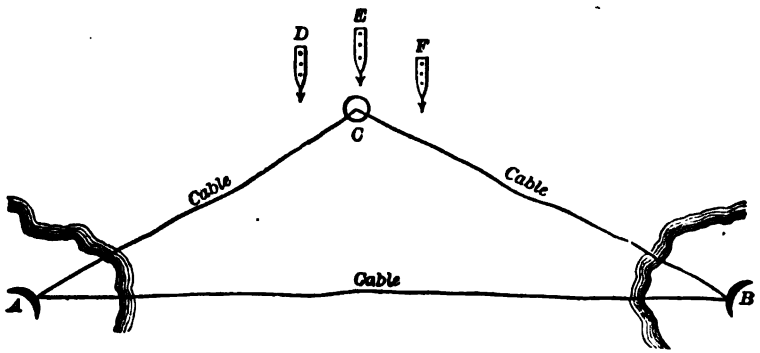
(1) *Mark buoys,* in addition to ranges, may indicate when an enemy approaches the line, and all the mines may be fired simultaneously by the operator on shore. Six 500-pound mines in a line, properly spaced, would thus defend a channel about 700 feet wide, as each mine would be effective at a distance of about 50 feet.

(2) *Judgment firing* may be used for a line of mines.

31. Ground mines.—Ground mines rest on the bottom. They may have contact buoys above them and be fired in the same manner as buoyant mines. If contact buoys are not used "judgment firing," or fire by cross-bearings, must be resorted to.

32. Ground mines are usually placed in shoal water. Sometimes, however, very heavy charges are moored in comparatively

deep water, especially when swift currents or a considerable rise and fall of the tide would render buoyant mines ineffective. In such cases there may be two stations on shore to fire by cross-bearings, as shown in the sketch. The observers at *A* and *B* may have plane-tables showing the bearings of the mines, and each may direct a telescope at an approaching ship and close a break in the firing-circuit whenever a ship is on the proper bearing. The two stations should be connected by telephone. Unless a ship is on the proper bearing from both stations at the same time, the two breaks in the circuit, one at *A* and one at *B*, will



FIRING GROUND MINES BY CROSS-BEARINGS. ART. 31.

not be closed simultaneously, and the mine will not be fired. This would be the case with the ships at *D* and *F*, neither of which would pass over the mine. But the ship at *E*, continuing her course, would pass over the mine, the breaks in the circuit at *A* and *B* would be closed simultaneously, the circuit would be completed and the mine fired.

33. Groups of ground mines.—In shoal water comparatively small charges, without contact buoys, may be used in ground mines, and they may be planted in groups, or lines, to be fired simultaneously, as described for a line of mines, either by cross bearings or by "judgment firing."

34. Ground observation mines.—Ground mines may be supplied with contact buoys and with a signaling- as well as a firing-

circuit, the cables being taken to the shore station, where the mines may be fired, singly or in groups, in the same manner as observation mines. In this case they are called "ground-observation mines."

35. Advantages of ground mines.—Ground mines, if securely moored, may not be affected by swift currents which would carry down and render buoyant mines quite useless. And if the rise and fall of the tide is not excessive, ground mines, especially with large charges, will be effective at all stages of the tide. If con-

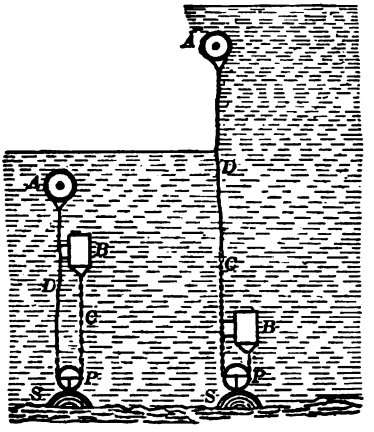


FIG. 1.—RISE AND FALL MINES. ART. 36.

tact buoys are not used, friendly vessels may pass over ground mines with no injury either to ships or to the mines.

Rise and Fall Mines.

36. When the rise and fall of the tide is excessive, buoyant mines which would be effective at high water might be on the surface at low water. Various methods have been proposed to keep buoyant mines, automatically, at a constant depth below the surface of the water, and although none of these inventions have been perfect in their action, the subject is of importance. One of the most reliable devices for tidal mines is shown in Fig. 1.

A is the buoyant mine-case; *B* is a buoyant counterpoise filled with air; *C* is a chain made of links varying in weight, the heaviest links being furthest from *B*; *D* is a mooring-rope attached to the chain; *S* is an anchor with a pulley attached through which the chain *C* reeves; to prevent twisting, the counterpoise is attached to the mooring-rope by rings, or guides, which permit it to rise and fall along the rope or chain.

37. The action is as follows: Beginning at low water, as the tide rises the increased water-pressure compresses the air in the

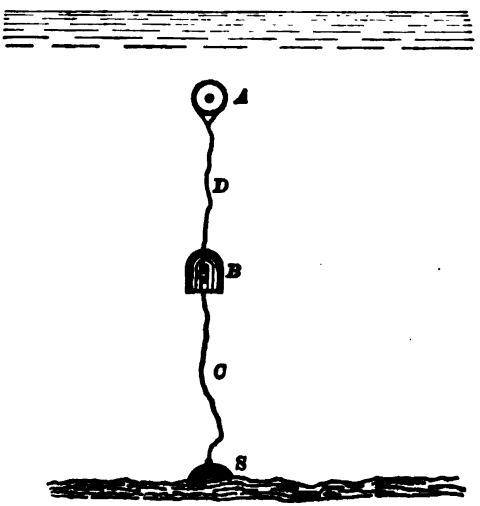


FIG. 2.—RISE AND FALL MINES. ART. 38.

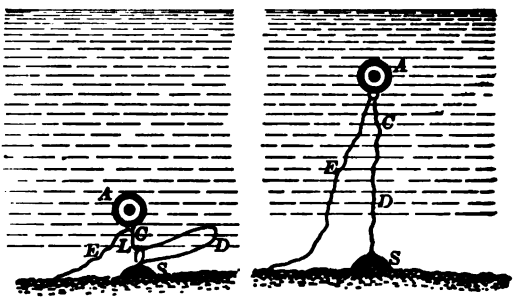
counterpoise, reducing its buoyancy; *B* sinks and *A* rises, therefore, until equilibrium is restored by some of the heavy chain passing around the pulley. When the tide falls, the reverse action takes place.

38. In another device, shown in Fig. 2, a buoyant regulator, *B*, contains a spiral wheel and a drum on a single axis, the part of the cable, *D*, being wound on the spiral wheel and being continuous with the lower part, *C*, which is wound on the cylindrical drum. The rise and fall of the water inside the regulator, which is open at the bottom, increases or diminishes the air pressure

and causes the drum and spiral to turn by the varying tensions on the parts of the cable. The relative buoyancy of the mine-case and the regulator, *B*, determine the diameter of the drum and the varying diameter of the spiral, so that the mine may be kept at a fixed depth below the surface.

Dormant Mines.

39. In order that friendly ships may use one or more channels with safety in entering or leaving port, the use of dormant mines has been suggested.



DORMANT MINES. ART. 39.

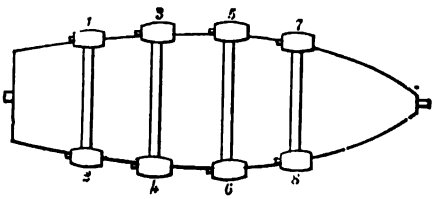
40. The figure shows the general principle of dormant mines. The mine case, *A*, is held down near the anchor, *S*, by an explosive link, *L*, which contains a small charge of explosive. When a hostile force appears, or an attack is anticipated, an electric current may be passed through the link, exploding the charge, destroying the link and permitting the mine to rise and become active. *E* is the electric cable for firing the mine.

Blockade Mines.

41. Until recent years submarine mines were regarded solely as a feature of the fixed defenses of seaports, and their employment by naval forces in active offensive and defensive warfare was not seriously considered. The practicability of their use by ships or fleets was not admitted until the activity of inventors

resulted in such a perfection of mechanical details in the application of electrical, safety, and self-anchoring mechanisms that the problem of handling mines—laying them and picking them up—has been greatly simplified. At the present time nearly all navies are being supplied with "naval defense" or "blockade mines," which are to be used by fleets in time of war, and it is reported that in one foreign service all large ships are to carry from 20 to 30 mines of an improved electro-mechanical or electro-contact type, with self-anchoring devices.

42. Mine-laying vessels.—Although it is expected that each ship, with its own boats and resources, may lay its supply of blockade mines in case of necessity, special mine-laying vessels have been suggested to accompany each fleet for the purpose of hand-

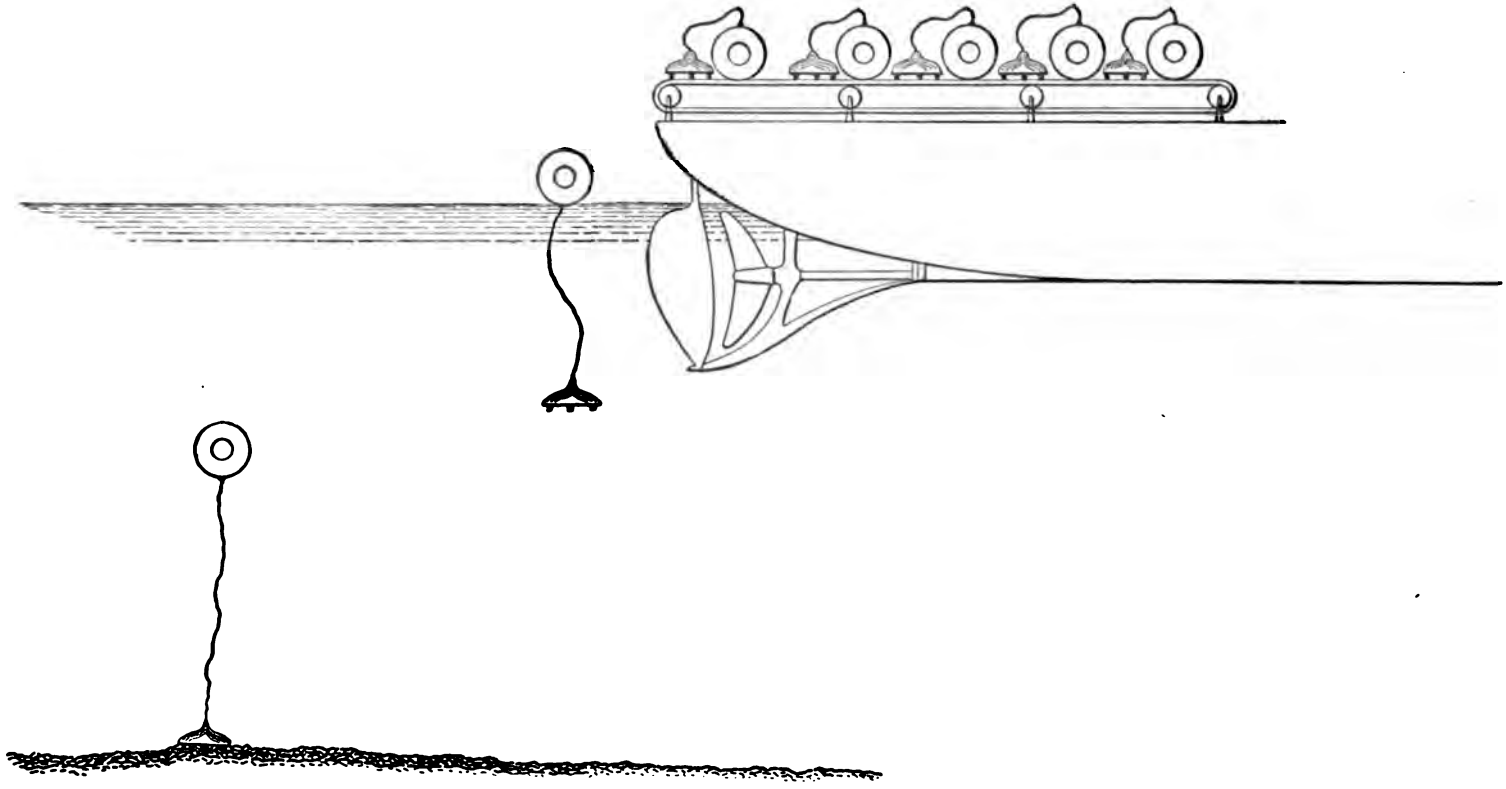


LAUNCH LOADED WITH MINES. ART. 44.

ling the mines with greater ease and expedition. Plate II will give an idea of one method of fitting a mine-laying vessel for this work.

43. The mines may be placed upon an endless traveling platform, similar to the floor of a treadmill, which will carry them with their anchors successively to the stern of the ship, where they may be permitted to drop off and anchor themselves at intervals and at a certain distance below the surface of the water, the ship moving at high speed. It is claimed that such a ship can anchor a large number of mines and pick them up again with ease—lay them in the forenoon and pick them up in the afternoon.

44. Laying blockade mines with a launch.—In case a cruising ship is required to lay a number of blockade mines with its own resources, there are several methods which may be adopted. The mines, with their anchors, batteries, and safety-breaks, may

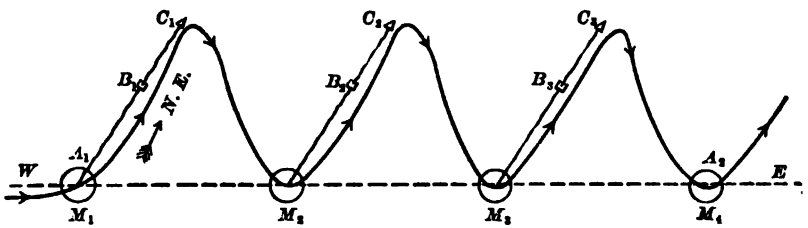


VESSEL LAYING SELF-ANCHORING BLOCKADE MINES.

be placed in a ship's launch at the ends of the thwarts as shown in the sketch, each being ready to slip at short notice. A steam cutter may then take the launch in tow.

45. Suppose the mines are to be laid in a line, A_1, A_2, from west to east, M_1, M_2, M_3, etc., being the mines, B_1, B_2, B_3, the batteries, and C_1, C_2, C_3, the safety-breaks for the several mines. Arriving at A_1, the first mine, M_1, with its anchor, is slipped, and the tow steers NE. until B_1 and C_1 are dropped successively. The helm is then put hard over and the tow returns to the E-and-W-line where M_2 is dropped, and continues to steer a zigzag course until all the mines are laid.

NOTE.—The same general method may be followed in laying mines, which have no "safety-breaks."



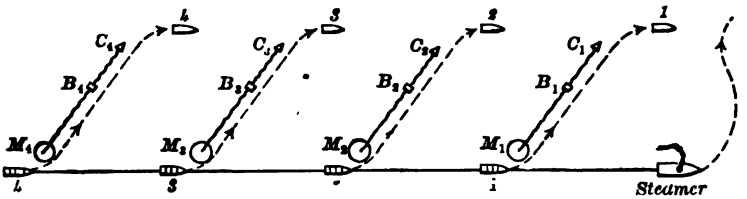
LAYING A LINE OF BLOCKADE MINES WITH LAUNCH IN TOW. ART. 45.

46. Laying blockade mines with several boats in tow.—Another method, which would be preferable under some circumstances, is to place each mine with its battery and safety-break in a separate boat, the mine and its anchor slung over the stern ready for slipping, and the crew seated on the thwarts ready to get up oars. Take all the boats in tow of a steamer, the lengths of the tow-lines or painters being equal to the distances at which the mines are to be spaced when anchored. The tow then proceeds, as before, to the point where the mines are to be laid and steers along the line, the crew of each boat being ready to slip its mine. When in position the towing boat makes a signal and all the mines are slipped simultaneously and *all tow-lines are cast off*. If the mines are dropped promptly, it will not be necessary for the boats to anchor. In case of a hitch, however, a boat may

anchor in position until its mine is dropped. All boats then get up oars and pull on parallel courses at 4 or 8 points from the line of mines and drop their respective batteries and safety-breaks as before. The steamer may then take the boats in tow again and return to the ship, if necessary, for another lot of mines.

47. In this manner each ship of a squadron may quickly lay a line of mines in accordance with a plan previously decided upon, and each ship's force, knowing exactly how and where its mines were planted, may pick them up without delay. The sketch illustrates this method, the boats, mines, batteries, and safety-breaks being numbered as before.

48. The future of blockade mines.—If the claims of inventors are even approximately realized, submarine mines may play an

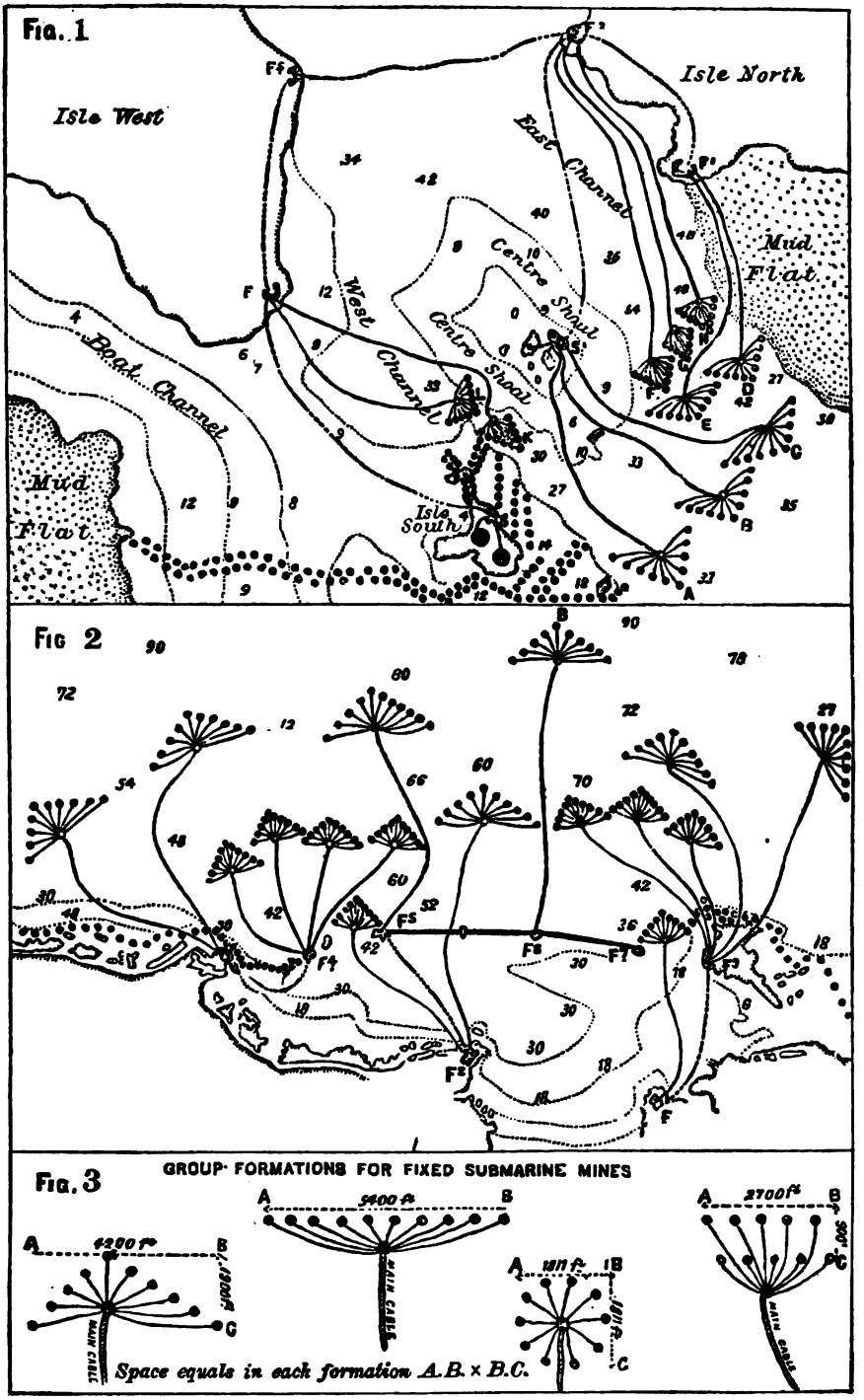


LAYING BLOCKADE MINES WITH BOATS IN TOW. ART. 46.

important part in future naval wars. A squadron, or a single ship, may protect itself from attack by quickly mining the approaches to a harbor in which it takes refuge; or an inferior naval force may successfully blockade an enemy in port by laying lines of mines across the entrance, and then protecting the mine field from countermining operations. With such a system of blockade mines, Cervera's squadron might have been effectively blockaded in the harbor of Santiago, leaving the greater part of Admiral Sampson's fleet free to engage in other operations. The subject is one of growing interest and importance.

Plan of Mine Defense.

49. The plan of mine defense to be adopted for any particular seaport can only be decided upon after a careful study of the conditions peculiar to that port—the character of the channels,



PLANS OF MINE-FIELDS.

the depth of the water, strength of currents, rise and fall of tide, etc. All these points having been carefully noted, the positions of the mines, or groups of mines, are laid down on the chart. As a general rule, ground and contact mines, singly or in groups or lines, are placed in shoal water, the former being preferred wherever the currents are strong. Groups of observation mines, or electro-contact mines, are usually placed in deep water and at outlying points, and the groups are so spaced that a ship passing between the groups of one line will pass over those of the line next inside. The mines are all numbered and a table of angles is given to the officer who lays the mines, so that they may be laid in accordance with the plan.

50. The mine-field.—The whole space occupied by mines is called the "mine-field." It should be swept by the fire of small guns to protect it from countermining operations, and by electric search-lights to guard against night attacks upon the mine cables. Plate III, Figs. 1, 2, and 3, shows the general plan of a mine-field and the group formations used for observation and electro-contact mines.

51. Spacing of mines.—If the plan of the mine defense does not contemplate that all the mines in one group, or line, are to be fired simultaneously, it is evident that care must be used to plant the mines at such intervals that the explosion of one may not cause those adjoining it to explode, or even to signal in the case of observation mines. It is not easy to give a rule for this distance, but one authority states that mines containing 100 pounds of gun-cotton should be spaced about 100 feet apart. The larger the mines the less desirable will it be to fire more than one mine at a time, and the greater must be the distance between them. Mines containing 500 pounds of gun-cotton should be spaced about 320 feet apart. For these reasons it is obviously wise to distribute the mines over a wide area and in many different lines. The complete removal of the mines by an attacking force will thus be rendered more difficult, and the expenditure of a few mines to beat off one attack may not destroy the whole mine-field, leaving the entrance open to a second attack. An enemy would prefer to pass over a limited field thickly planted with mines, because the

leading ships might clear the way for those in rear. But he will dread the passage over a field of great extent where each mine acts singly—where no ammunition is wasted.

52. Friendly channel.—A special channel across a mine-field is sometimes designated for the use of friendly vessels. It may be planted with ground or dormant mines to prevent its use by an enemy, while friendly vessels may pass over such mines with safety.

53. Testing mines.—It is most important that a mine-field should be kept in an efficient condition by providing all facilities at the observing station on shore for testing, daily, the firing-circuits of all electrical mines.

Mine Destroying.

54. The quickest way to put a mine-field out of action would be to cut, near the shore, the cables that lead to the observing stations. This of course would only be possible at night under peculiarly favorable conditions and in the absence of a defending force. If this plan of attack is impracticable, there are three other methods that may be resorted to:

(1) Creeping.
(2) Sweeping.
(3) Countermining.

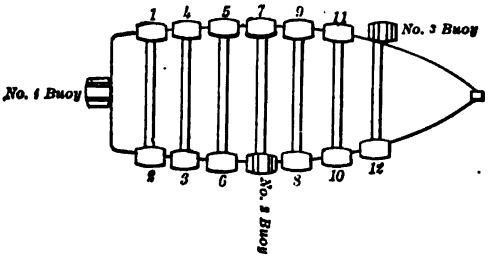
55. All these methods of removing or destroying mines to clear a passage for ships are difficult and dangerous, inasmuch as the force engaged in the work may be under the fire of guns that command the mine-field, or may be attacked by vessels specially assigned to protect the mines from destruction. As a rule, such operations should only be attempted at night.

56. Creeping.—This consists in supplying boats with grapnels with which to drag the mine-field for cables, junction boxes and disconnectors. Sometimes explosive grapnels are used with which to destroy the cables or connections. This method is used in shallow water and as near the shore as possible in order to get hold of the cables.

57. Sweeping.—This consists in dragging a weighted rope, chain, or long iron bar between two boats some distance apart.

Grapnels and explosive charges are sometimes attached to the sweep. If cables, or junction boxes, are brought to the surface they may be cut or destroyed. Anchors may be pulled up so that the mines will come to the surface and float away.

58. Countermining.—This method consists in running lines of mines across the field and then exploding them in order to destroy the connections or cause the defending mines to explode by shock. Countermines sometimes contain very heavy charges—500 pounds of gun-cotton. All the mines in one line are attached to a single cable so that all may be fired simultaneously as soon as the last mine is dropped.



COUNTERMINING LAUNCH. ART. 59.

59. Countermining boats.—Ships may be supplied with countermining boats specially designed for the work. It is important that each boat should carry from eight to twelve mines and that arrangements should be made to run out a line of mines quickly. When special boats are not provided, a heavy sailing-launch may be fitted for the purpose, as shown in the sketch.

60. The mines with their sinkers are slung over the sides of the launch at the ends of the thwarts. For a long line of mines three buoys are provided, which, with their separate anchors may remain in position at the extremities and middle of the line after the explosion to mark the ground that has been cleared. All the mines are attached to one strong cable, and are spaced according to the weight of the charges. The cable is coiled clear in the launch and the bights pass under the boat from one mine to another on the opposite side. One end of this cable is carried in a

battery boat which is towed astern of the launch and which anchors before the first buoy is dropped; the other end of the cable is taken on board the steamer, or gunboat, which takes the countermining launch in tow. The mines and buoys are held by slip-stops so that they may drop automatically when a strain comes on the cable. It should not be necessary to have a crew in the launch.

61. Running a line of countermines.—All being in readiness, the tow starts at full speed for the point of attack. At the proper time the battery boat in rear of the launch slips its tow-line, at the same time anchoring and also slipping No. 1 buoy at the stern of the launch. The launch continues on, towed at full speed, the cable being paid out until it tautens and slips No. 1 mine. The other mines and buoys are slipped in turn when the strain comes on the cable, and finally No. 3 buoy drops. The towing steamer then makes a signal and closes the firing-battery at its end of the cable; the battery boat, seeing the signal, also presses the firing-key and the line of mines explodes. The lines of countermines may be laid with a view to clearing only one channel—that is, lengthwise and near the middle of the channel. In case the channel is wide, two parallel lines may be run at a certain distance apart to insure a safe passage for ships. A channel having once been cleared, the defenders should not be permitted to plant new mines. They may seek to re-mine a channel by using simple contact mines to prevent delay, dropping them at night or in thick weather. This operation will be easier than that of countermining. It is far simpler to defend or replace, than to attack or destroy a mine-field.

62. Recent events in the East have emphasized the importance and demonstrated the effectiveness of mines in naval warfare. And the great danger to friendly and neutral ships from the use of floating or contact mines has also been shown (see Art. **14**).

CHAPTER XXXVI.

FIELD FORTIFICATIONS AND INTRENCHMENTS.

NOTE.—Ingersoll's Text-book of Ordnance and Gunnery, and the Manual of Military Field-Engineering, by Captain Wm. D. Beach, U. S. Army, were consulted in the preparation of this chapter.

1. A judicious use of fortifications may enable the weaker body of men (from whatever cause) to become equal to, or stronger than, a superior force; a knowledge of its principles assists in occupying a position to the best advantage, the artificial construction being so combined with the natural features of the ground as to produce from a minimum of labor a maximum of strength.

2. Trenches and ditches.—A trench is an excavation in rear of the covering mass; a ditch is one in front of it.

(1) Cover is more rapidly gained by the use of a trench, as it will be obtained by the excavation plus the height of earth thrown immediately in front.

(2) A ditch might provide the earth for the parapet in works of a more important nature, and at points which are purely defensive. The bottom of a ditch may be formed in a V shape with advantage, in order to prevent the attack from accumulating there.

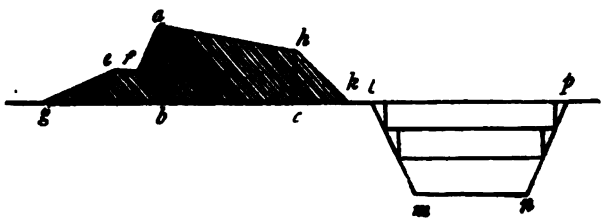
(3) All works are made up of two parts the *profile,* and the plan or *outline.*

3. Profile.—The profile is a section shown by a vertical plane at right angles to the direction of the work. The profile selected will depend upon the object the work has to fulfill, upon the projectiles it may have to withstand, and upon the nature of the surrounding ground.

4. The profile may be formed also of a trench and a ditch, the men working on each side of the parapet, and throwing the earth upon the intermediate space. By these means a considerable thickness of parapet may be obtained in a short time; but in

such a case the ditch does not become deep enough for a sufficient obstacle, but may be subsequently deepened, the earth being thrown upon the crest of the counterscarp and forming a sloping surface called a *glacis*.

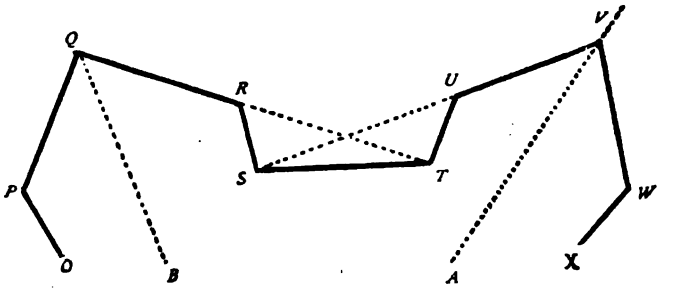
5. The profile shown is that of a parapet and ditch. The dimensions are obtained by the following considerations: the *command, a b,* by the amount of cover required to screen the interior of the work and the position of the enemy; the *thickness, b c,* by the nature of the projectiles likely to be used against it, for field artillery 12 feet to 15 feet, and for rifles 4 feet (these dimensions may be lessened, except for rifles, for the rear faces of works); *e f,* the *banquette,* is to enable riflemen to fire over the parapet, and is made 3 feet wide for a single rank of men, and 4 feet 6



PROFILE. ART. 5.

inches for a double rank; *e g,* the slope leading to the banquette, has a base equal to double its height; *a f,* the *interior* slope, is *revetted* (it being so steep as to require artificial support); *a h,* the *superior* slope, is sufficiently sloped to enable the defenders to see the top of the *counterscarp,* and, upon level ground, is as 1 : 6; *h k,* the *exterior* slope, is an angle of 45°; *k l,* the *berm,* is made sufficiently wide to relieve the escarp from the pressure of the parapet; *l m,* the escarp, usually slopes about 2 : 1 if the soil be strong, and as much as 45° in sandy soil; *p n,* the counterscarp, is made as steep as the earth will allow, as it has no weight to bear like the scarp. The ditch is from 6 feet to 12 feet deep, and should be at least 12 feet wide at the top. The slopes of the ditch are obtained by excavating it in steps, as shown in the sketch, the depth and base of the steps being in proper proportions; these steps are subsequently cut away.

6. Outline.—The outline is the general arrangement, or trace, of works upon the ground. As much direct and flanking fire as possible must be brought to bear upon points of attack. In very uneven ground, where direct fire cannot be given, there will always be found some points from which flanking fire may be obtained. The three points to be considered are: 1st, the object of the work, that fire may be given in the required direction; 2nd, that its own ditches shall not be dead, that is, unseen by the fire of the defenders, and that the ground over which the attack must be made shall be under fire from the work; 3d, that those defending the work shall be protected from oblique, enfilade or raking, and reverse fire.



P Q R and *U V W*, Advanced Parts.
R S T U, Retired Parts.
P Q, *Q R*, *U V*, *V W*, Faces.
R S, *T U*, Flanks.
S T, Curtain.
Q T, *S V*, Lines of Defence.
P Q R, *U V W*, Salient Angles.
R S T, *S T U*, Re-entering Angles.
V A, *Q B*, Capitals.

OUTLINE. ART. 6.

The outline, therefore, will depend upon the object of the work and the natural features of the ground.

Definitions.

7. The following definitions and simple rules will be found useful:

The extent of the work will be determined by the number of men required for its defence. Two men per lineal yard of the parapet, with half that number in addition as a reserve, were formerly considered an ample garrison in most cases; but in the

present day, taking into consideration the greater use of curved fire of shells, the precision of rifled artillery, and the rapidity of fire with breech-loading small-arms, it would be inexpedient to crowd men together. One man per running-yard, and half that number in addition as a reserve, will probably be sufficient for most positions. Field-guns will each occupy a length of 15 feet upon the faces of works, and 40 feet (20 feet on each side) at the salient angles.

8. Splinter-proof traverses, 4 feet wide at top and 6 feet wide at bottom, may be placed between field-guns, and to give protection from enfilade or oblique fire. Those of similar construction, to give cover from reverse fire, are called *parados traverses;* within such traverses magazines may be conveniently formed. When the interior space is limited in a field-work, the magazine may be placed under the parapet.

9. A salient angle is formed by two faces projecting outwards, towards the enemy. Such angles, being points of attack, should be as few and as prominent as possible, so that the points of attack may not be doubtful, and may be well prepared for defence. They should be as obtuse as possible, and not less than 60 degrees, in order that a greater extent of ground may be seen from the parapet, and they should be situated upon the higher points of ground, in order that the interior of the work may be the better screened. See *P Q R* in the sketch.

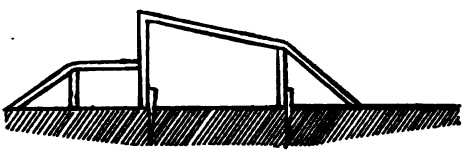
10. A line of defence is the face of a work, which, together with its ditch, receives flank defence. In detached works which mutually flank each other, it consists of the portion which is flanked, together with its distance from the flanking work. For the close flanking of ditches, lines of defence should never be greater than 300 yards. The distance between detached works, in order that the ground in front of them may be defended by the artillery fire of the collateral works, may extend to 1500 or 2000 yards. Faces of works will usually average from 40 to 60 yards, and should be directed clear of a raking fire from the front; this will usually be the case when the salients are obtuse; the prolongations of all faces of works should, if possible, be directed upon points where it is impossible to establish batteries, such as marshes, etc. See *Q T, S V,* in the sketch.

11. An angle of defence is the angle contained by the flanking portion and the line of defence. The limits are from 90 degrees to 120 degrees; about 100 degrees is best.

12. The capital of an angle is the imaginary line bisecting it, along which the enemy advances. That portion of the capital under fire should be made difficult of approach by the use of obstacles. See *V A.*

13. As a corollary to the rule that salient angles should occupy the higher points of ground, re-entering angles will necessarily occupy the lower points. The openings or communications through works, which may be necessary, are formed near the re-entering angles.

14. Flanks should never be less than 12 yards long, otherwise the ditch will not be seen, much of this space being occupied by



RIGHT PROFILE. ART. 15.

the slopes of the portion which is flanked. When it is advisable to flank with artillery, not less than three guns should be used.

Construction of Single Field-Works.

15. Pickets are to be driven at the salient and re-entering angles, and tape or string passed round them. The lines traced are the crest line (or highest part of the work) and the lines marking the excavation for trenches or ditches. With ditches, these lines will be the crest of the work and the edge of the escarp and counter-scarp; if with trenches, it will be sufficient to mark the front line of the trench only. "Profiles," or skeletons of the work, are then set up, formed of slips of wood, secured to pickets driven into the ground; or they may be formed with wood, cut to the proper lengths, for the heights of the various slopes, connected at their ends with rope yarn.

16. The berm is generally left rough, and dressed upon the completion of the work.

17. Upon long faces at least three profiles should be set up. At the angles of the work oblique profiles are erected, whose dimensions will, of course, vary with the sides of the angles.

18. It is advisable to divide the working party into squads of 25 men, each squad having a responsible overlooker. With trenches it is best to place the men at intervals of 6 feet along the tracing line, each man having a pick and shovel. When all is ready, the work is commenced simultaneously, each digger beginning at the left of his task, and getting cover to the required depth as quickly as possible, and then extending the excavation to his right.

19. With ditches, place the diggers along the escarp line, facing the work, each with a pick and shovel, at intervals of 6 feet. *Shovelers* are placed upon the ground to be occupied by the parapet, in the proportion of two to each set of three diggers (the whole number being, therefore, one-third less than that of the diggers); these have shovels only. *Rammers* are placed in the proportion of one to each pair of shovelers, in order to consolidate the earth; they should not allow more than 6 inches in depth to accumulate without ramming it well. Suitable instruments for their use are of very easy construction. The ramming is not done with a view of resisting projectiles, as loose earth will do this better, but with the object of solidifying the work.

20. Revetments.—Earth newly dug will not stand at the steep slopes required for some portions of the work; the means used to effect this are called *revetments; hurdles* or mats, 6 feet long and 2 feet 9 inches high, and made of brushwood, with vertical pieces called pickets, may be readily formed; 10 pickets will be a good number for each hurdle. A *gabion* is a cylindrical hurdle, filled with earth when placed in revetment; gabions are 2 feet in diameter and about 3 feet high; *fascines,* or bundles of brushwood, from 7 to 9 inches in diameter, and of various lengths, are very good for this purpose; they are bound together by tough twigs, at intervals of about 18 inches; this revetment is built as the parapet is raised, and secured to it by means of pickets driven into it at angles of 45°, each row of fascines being also picketed to the row beneath; the joints of the rows of fascines should be broken; it is necessary to use revetments for the interior slopes and cheeks of embrasures; if fascines cannot be procured, planks, casks or sand-

bags may be used for this purpose. Magazines are frequently constructed on the unexposed sides of traverses, as follows: Place strong splinter-proof timbers at an angle of 45° against a well-revetted traverse, strengthened by bags of earth and sods, the whole being covered with tarpaulins.

Obstacles.

21. Obstacles have for their object the holding of an enemy under fire while checking his advance and breaking up his formation.

(1) They must be within the effective range of the defender's fire.

(2) They should not be visible to the attacking party until the latter is at close range.

(3) They should be difficult of removal under fire.

(4) They must afford no shelter to an enemy.

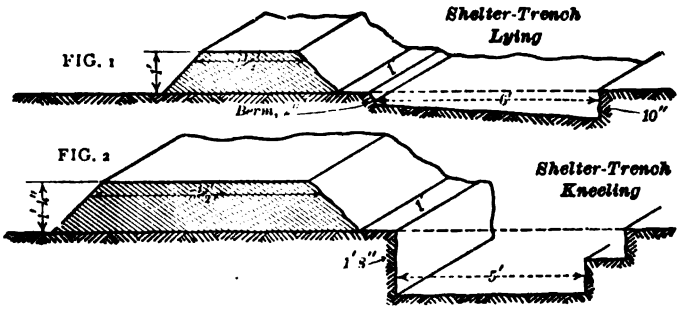
22. To hinder the approach of the enemy, keep him under the fire of the intrenchments, and render an assault as difficult as possible, are most important points in the defence of field-works; and it must especially be borne in mind that obstructions should always be placed in the unflanked ditches. *Palisades* made of young trees, or of large ones split into two or three pieces of a triangular shape and pointed, 10 feet long and 6 or 8 inches thick, are very useful when placed either upright in the middle of the ditch, or at the foot of the escarp inclining outwards; they are planted 4 or 5 inches apart, and buried 3 or 4 feet in the ground. The lower ends under ground are connected by a riband or cross-piece to prevent them from being torn up separately; another riband is also used to connect them at about 1 foot from the top.

23. Abattis are constructed of trees or stout branches having their ends pointed or fastened to the ground with strong pickets, the branches being turned toward the enemy; for putting a village into a state of defence, trees bordering the road can easily be turned into a serious obstacle by sawing half through their trunks and fixing their heads to the ground.

24. Trous de loup are also very useful placed in front of the counterscarp, especially at the salient angles; they are pits of

either 3 feet in width and depth, or of double these dimensions; a sharpened palisade is placed in the center, the point is not to project above the mouth of the pit; on no account should the pits be made 4 or 5 feet deep, as the enemy might then turn them into rifle pits.

25. Barbed-wire.—Barbed-wire fences have been used in recent wars to check an attack. Wire entanglements, both high and low, made by driving stakes into the ground and connecting them by stout wire, are also used. All such obstacles are particularly useful at night.



SHELTER-TRENCHES. ARTS. 27 AND 28.

Hasty Intrenchments.

26. Hasty intrenchments are such as may be made with little delay after occupying a position in the field; they consist of cover or shelter-trenches for the men, and gun-pits or epaulments for artillery.

27. Shelter-trench lying.—The shelter-trench for skirmishers lying down is shown in Fig. 1. It gives a protection of 2½ feet of loose earth, which will stop small-arm bullets under ordinary circumstances. The time required for one man to make 5 feet of this trench with a small intrenching spade is about 25 minutes. Ordinarily two men may use 5 feet of this trench, though three may occupy five feet by lying on their left sides. In firing, the left elbow rests on the berm.

28. Shelter-trench kneeling.—To get cover kneeling, deepen the lying-down trench to 1 foot 8 inches, and make it 5 feet wide

with an embankment in front having a height of 1 foot 4 inches with a resulting thickness of about 5½ feet (Fig. 2). The time for one man to deepen the trench in this manner, with a small intrenching-tool, is about 45 minutes.

29. Men may fire from this trench kneeling in double rank, four rifles for each 5 feet of trench. Four men could make 5 feet of this trench from the beginning in about 20 minutes.

30. Cover for artillery.—Cover for guns may be obtained by means of gun-pits made by digging a hole of a size sufficient to partially conceal the gun and its crew, and forming an embankment in front with the excavated earth. The "Austrian Gun-Pit" is often used.

31. Gun epaulments.—Instead of placing the gun in the bottom of the pit, it may rest on the natural surface of the ground and be covered by an embankment in front, made by digging two pits, one on each side of the gun. The crew may find cover in these pits.

32. Advantages and disadvantages of shelter-trenches.—The advantages are:

(1) They stop rifle bullets.

(2) They offer a small target.

(3) They are quickly and easily made.

33. The disadvantages:

(1) The embankments being low, the field of fire may be limited by small folds in the ground unless care is taken in selecting the position.

(2) In wet weather they may become untenable by reason of mud and water.

34. Gun-pits have practically the same advantages and disadvantages as shelter-trenches.

Lines of Works.

35. A line of works may have *intervals,* or it may be *continuous.* A line with intervals has the following advantages:

(1) It involves less labor.

(2) The garrison may be smaller.

(3) It allows greater freedom of movement for counter attacks.

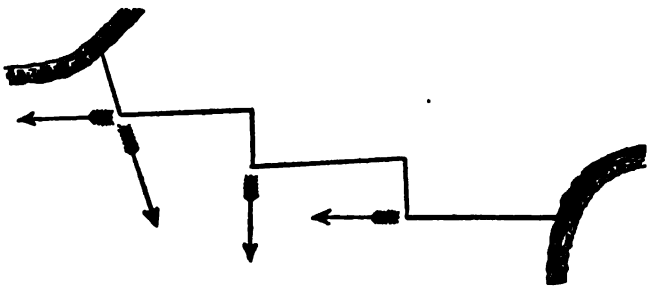
36. Such works are usually so placed as to mutually flank each other; that is, in echelon.

37. In the case of continuous works the line may be an *indented line*, or a *right line*. From the latter only a direct fire can be obtained, while from the indented line both a front and flank fire may be practicable, as will be seen from the sketch.

A Defensive Position.

38. A position of perfect defence may not always be possible, but the following general advantages should always be sought:

(1) The position should conform to the tactical requirements of



INDENTED LINES. ART. 37.

the occasion and should favor the effective use of the principal weapon of the defenders.

(2) The flanks should be as secure as possible against a turning movement.

(3) It should be impossible for the enemy to obtain natural cover during his advance; that is, the defenders should have a free field-of-fire.

(4) The defenders should be protected from the fire and view of the enemy by cover, natural or otherwise, which will not interfere with counter attacks.

(5) The position should be such that the defenders may move readily from one part of the line to another.

(6) The advance of the enemy should be delayed by obstacles and entanglements.

39. It was formerly the function of engineers and pioneers to lay out and construct defensive works. It is no longer their exclusive province. It is now accepted as a principle that the men who are to defend a position must prepare it for defence. Cover is of greater importance than ever before in the history of warfare. Modern weapons and smokeless powder have emphasized the importance of cover.

40. To occupy and defend a town.—A town when properly prepared and defended may have the following advantages:

(1) It may be rapidly placed in condition for defence.

(2) It conceals the strength of the defenders.

(3) It provides a certain amount of cover from fire.

(4) It affords shelter from the elements.

41. On the contrary, it has the following disadvantages:

(1) The garrison is scattered and not easily controlled.

(2) When under artillery fire, splinters and fragments may cause casualties.

(3) It may be set on fire by shell-fire.

42. A town may be held for the following reasons:

(1) As a supporting point in the main line.

(2) As an advanced post in front of the main line.

(3) As an independent post.

(4) As a reserve station, or rallying point, in rear.

43. The following are some of the preparations to be made for the defence of a town:

(1) First select some suitable and substantial building as a stronghold and determine whether it would be best to occupy the whole village, or a part only. Avoid wooden houses and thatched roofs, and prefer brick houses to those of stone, selecting such as mutually flank each other. Take care that the amount of ground occupied be not in excess of the number of men available for the defence. Salient points must be strengthened as much as possible; all houses not occupied by the defence which may be of the least use to the attack must be demolished. *Outside* the defences destroy all walls, thick hedges, and any cover which may be parallel generally to the place, and leave such as may be perpendicular to it, and which will therefore be enfiladed and cause

obstruction. *Inside* the place, reverse this rule; *wet* ditches, palings, and thin hedges outside the place may all be left. Hedges, walls, etc., may be incorporated with the general line of defence. Long walls may receive flank defence by means of *tambours* or projecting small angular works or stockades; communications may also be thus covered. The streets may be barricaded and the houses loopholed; great care must be given to the communications with the stronghold, and also that barricades be not in positions to be taken in reverse; in this case other barricades must be formed in rear. Field-guns must be placed in commanding and retired positions difficult of access.

(2) A sufficient garrison for a building will be at the rate of 1 man for every running 4 feet of the lower story, 1 man for every 6 feet of the second story, and 1 man for every 8 feet of the upper story, should there be one. All windows and doors of the lower stories should be well barricaded and secured, and ditches cut around the house. Doors may be barricaded by heavy furniture filled with earth or by sand-bags; doors should, if possible, be made bullet-proof by nailing upon them additional planking. The glass in all windows should be at once demolished, and the window frames filled up with rolled blankets, carpets, etc. If there be no time to destroy all the glass, blankets secured by forks within the window frames will prevent splinters. Loopholes should be made in the walls and at the angles. The upper windows need not be barricaded throughout, but must be so to a height of 6 feet from the flooring. Balconies may be strengthened and made bullet-proof, being loopholed at the base in order to give fire from beneath to the foot of the wall; suitable overhanging constructions of a similar nature may be formed by means of timber, these being passed through the wall and secured inside to the joists of the flooring; it would be advisable to construct them over outer doors. Especial care must be given to the communications inside the building, staircases being partially removed and ladders substituted. If the outer wall be liable to be weakened by artillery fire, the flooring inside should be supported in addition by stanchions. Plenty of water must be available, in casks, etc., within the building.

(3) Loopholes should be made as small as possible, the width at the neck never being more than 3 inches.

44. Hedges and walls.—Hedges and walls serve as screens, and with ditches on either or both sides, the earth being thrown against them, they may afford more or less cover. To prevent their being used by the enemy in case they are abandoned or captured, the ditch on the enemy's side should be so deep that he cannot fire through or over them.

45. Concealment of trenches and gun-positions.—It is of the utmost importance that all trenches and gun-pits, or gun-positions, should be covered with branches, weeds, sod, etc., in order that their position and extent may not be discovered. The old rule, "fire draws fire," is now changed to "visibility draws fire," and all problems in attack and defence must consider this principle first of all. Smokeless powder is a great aid to the defender in that it does not betray his position.

Defensive Tactics of the Boers.

46. The success of the Boers on the defensive was due not only to the judgment displayed in the selection of a position, but to their skill in concealing it. Their trenches were usually without embankments. After digging the ditch the earth was leveled off. There was nothing to betray their position. Their artillery was usually dispersed, and every gun carefully screened. The English often found themselves under fire without knowing from what point the fire came. There being no smoke, and the enemy being completely screened, or having burrowed in the ground, the fire could not be returned. It must be evident that such conditions would be extremely trying and demoralizing to the attacking force.

47. The Boers often occupied widely separated positions, and their trenches were seldom continuous but were placed at all advantageous points where a clear field-of-fire could be obtained, and sometimes in several lines which would be occupied in turn as they fell back. Their plan was to conceal every rifle and every gun and utilize the full power of every weapon by appealing to the individuality and marksmanship of their men.

Successful English Tactics.

48. Against these tactics of the Boers the English finally won their greatest successes by the adoption of extended-order formations at all times. Instead of concentrating and massing their men while on the march from point to point, they often swept over the country in long lines of skirmishers—they marched in extended order. Brigades kept in touch with each other, and battalions of eight companies marched in column, each company deployed as skirmishers at five paces interval, and the companies following each other at distances of about 200 yards. Thus a battalion would be about a mile deep. When one part of this long, thin line would find itself seriously opposed, or under fire, it would usually halt, take cover, and hold its ground until the distant parts of the line, continuing the march, would threaten the flanks and rear of the Boers and force the latter to leave their position. The English line would then resume the march and regain touch. This formation was known as "awaiting shell." It minimized the effect of the Boer's artillery and infantry fire, and reduced the chances of a disastrous surprise.

Field Intrenchments and Tactics.

49. It is laid down that the question of fortifications and intrenchments is essentially tactical. The examples of the Boer War demonstrate the truth of this statement. The location and the nature of field fortifications or intrenchments depend primarily upon tactical situations.

Naval Brigades on Shore.

50. It is not to be expected that purely naval forces will be called upon to construct permanent fortifications or to engage in independent operations on shore requiring an extensive knowledge of field engineering. The brief discussion of the subject in this chapter may suffice for most situations in which a naval officer may find himself.

51. Naval landing-forces may be required to man permanent fortifications already constructed, to seize and hold towns or other

positions, or to attack the same. The lessons of recent wars, both as regards offensive and defensive tactics, should not be forgotten. But it will, of course, be apparent that the open-order formations, and the tactics used against the Boers, who were expert marksmen armed with modern magazine rifles using smokeless powder, may not be practicable against another enemy differently armed.

52. Formations in mass, for mutual support, both on the march and in action, may be required against an uncivilized or semi-civilized enemy whose tactics are to surround and come to close quarters with his opponent. Such were the squares used by the British in the Soudan.

53. The officer must choose the formations and make the disposition of his force which may be required by the existing conditions. There is range enough in the Drill-Regulations to cover most cases if an officer applies them in a practical manner.

CHAPTER XXXVII.

PRACTICAL NAVAL GUNNERY.

Prepared by LIEUTENANT-COMMANDER W. S. SIMS, U. S. Navy, and LIEUTENANT RIDLEY MCLEAN, U. S. Navy.

1. Definition.—Ordnance is a term ordinarily applied to heavy weapons of warfare, such as great guns, howitzers, artillery, etc. In naval parlance, however, it has grown to be a general term which includes all material used on board a naval vessel for firing projectiles at the enemy.

2. Gunnery is the art of using the ship's guns to the best advantage; that is, in such a manner as to make the greatest possible number of hits in a given time.

Principles of Gunnery.

3. Excellence in gunnery is measured by the rapidity of hitting the point of aim. It is evident that however large a percentage of hits a gun may make, if these hits are not made with the greatest possible rapidity, the gun will have failed to attain its highest degree of usefulness. Similarly, the very highest degree of rapidity of fire, with inaccurate pointing, is entirely useless. Excellence in gunnery may therefore be regarded as the product of its two essential elements: 1. Accuracy of fire, and 2. Rapidity of fire.

4. Accuracy of fire.—This depends on:

(1) The accuracy with which the gun is pointed at the target or the enemy, or briefly, *accuracy of pointing.*

(2) The correctness of the position of the sight each time the gun fires, or briefly, *correct sight-setting.*

5. Accuracy of pointing depends on:

(1) *The individual skill of the pointer,* which is developed:

(a) By continued preliminary practice at his own type of gun.

(b) By pointing at the horizon, or at floating objects when the ship is rolling, and

(c) In actually firing his gun at target-practice.

(2) *The condition* in which the sight, the gun, the mount, and the various appurtenances which affect accurate shooting are kept.

6. Unless the gun, the gun-gear, gun-mount, and gun-sights are maintained in such a condition that the mechanical difficulty experienced by the pointer in aiming and firing the gun is a minimum, the accuracy of pointing will be affected. This applies not only to the condition as regards cleanliness, but particularly to the condition as regards facility of operation, and to the proper functioning of each individual part. A neglected gun-mount renders pointing difficult, and hence conduces to inaccuracy. Neglected sights always invite disaster; if they are actually out of adjustment when firing begins they insure a string of misses; if they are weak and liable to derangement they are apt to jar out of adjustment during a string of shots and thus invite disaster in action. Neglected firing-connections, locks, etc., invite either hangfires, missfires, or prolonged firing-intervals, all of which are serious hindrances to accuracy of fire.

7. Correct sight-setting depends on:

(1) The accuracy of the orders given by the division officer, or the gunnery officer, to the sight-setter, concerning the setting of the sights. This depends upon the accuracy with which the sight-bar range has been determined, which may be regarded as the most difficult problem in naval gunnery.

(2) The promptness and accuracy with which these orders are obeyed.

8. It is manifest that however perfect the gun, the mount, the crew, and the ammunition, unless the sights are correctly set at the moment each shot is fired the projectile will certainly miss.

9. The accuracy of the orders given to the sight-setter may for convenience be subdivided under the headings:

(1) When firing guns singly at measured ranges.

(2) When firing guns singly at unmeasured ranges.

(3) When firing all guns of a ship's broadside together at unmeasured ranges.

10. Firing guns singly at measured ranges.—This is the most elementary stage of target-practice. In this case (which is the case under which ordinary record target-practice is held) the entire responsibility for the correct setting of the sights falls upon the division officer; he must keep himself informed as to the true distance from the target at every instant of time, and by observation of the fall of the shot he must so correct these varying distances that the sight-bar ranges which he gives to the sight-setter will insure that any shot which is accurately aimed at the center of the target, will hit it.

11. Firing guns singly at unmeasured ranges.—In this case the ranges are determined by the range-finding party, by such means as exist on board ship, and are transmitted by the gunnery officer to the battery, by the range-indicators, or by such other means as may be provided. In this case the observations of the fall of the shot are made by the gunnery officer and his assistants, and the necessary corrections to the distances determined by the range-finding party are applied by this officer, because from an elevated position such corrections can be more accurately estimated, especially at long ranges, than by the division officer from his station near the gun.

12. Firing all guns of a ship's battery together at measured ranges.—(1) In this case the range is determined by the range-finding party, and transmitted by the gunnery officer to the battery in the same manner as above described. The correction to the various distances would be determined by the gunnery officer from the average center of impact of the various trajectories, and this would be applied by him, and included in the various ranges which are transmitted, so that nothing remains to be done but set the sight to the range and lateral compensation that are transmitted.

(2) In both this and the preceding case, the great importance of every gun-pointer being a trained expert, of every pointer aiming directly at the center of the target, and of all sights being set exactly alike (*i. e.*, at exactly the range and lateral compensation ordered by the gunnery officer) is apparent. This will cause the

shots to be bunched somewhere, and the gunnery officer can then quickly alter the sights of the battery so that this bunch will fall on the target, whereas, were this not the case, the shots from the battery would be so dispersed that no deductions could be made by the gunnery officer to guide him in the determination of the error existing between the distances determined by the range-finder and the actual sight-bar range which should be used.

13. Promptness and accuracy with which orders regarding the setting of the sight are obeyed.—(1) Regardless of the accuracy with which the ranges may have been determined, or of the skill of the gunnery officer in fire-control, unless the sights are promptly and accurately set to conform to the ranges given (in the first of the above cases by the division officer, in the second and third cases by the gunnery officer) all excellence in other features affecting gunnery are nullified.

(2) Whatever the method employed in carrying out the practice, the sight-setter's duty remains the same; it is to set the sight as accurately and as quickly as possible both laterally and in elevation each time a new range or a change in lateral compensation is ordered; and as the pointer always aims at exactly the same place, and as all errors are corrected by altering the sights, it is impossible to attach too great importance to this feature of naval gunnery.

14. Rapidity of fire.—This depends on:

(1) The rapidity with which the gun is loaded after it has been fired, or briefly, *rapidity of loading*.

(2) The promptness with which the pointer fires after the gun is "ready," or briefly, *rapidity of pointing and firing*.

15. Rapidity of loading depends on:

(1) The rapidity with which each member of the gun-crew performs his allotted duty.

(2) The "team-work" of the gun-crew. That is, on each member of the gun-crew performing his own duty in the service of the gun at exactly the proper time and in exactly the proper sequence, and then getting out of the way so as not to interfere with the other members of the crew.

(3) The *precision* with which each member of the gun-crew performs his allotted portion of the drill.

16. Accuracy and thoroughness in every detail, even though it may require slightly more time, is an absolute requisite to real rapidity of *continuous* loading, because in the commendable eagerness for excessive rapidity, many serious delays are caused by interference, confusion, and casualties that can be avoided only by precision in every movement; and it must be remembered that some of these delays, such as the raising of one single burr, or the jamming of one cartridge-case, may more seriously interfere with rapidity of fire than the maximum deliberation necessary to surely avoid them.

17. Rapidity of pointing and firing depends, like accuracy of pointing, on:

(1) The skill of the pointer.

(2) The condition of the gun, gun-mount, sights, etc., but particularly on the condition of the mount and firing-connections.

18. A really skillful pointer will keep a gun of an intermediate caliber, which is mounted on a modern gun-mount, continuously pointed at the target, provided the mount is maintained in a perfect condition. In this way the gun is aimed and prepared to fire the instant the pointer is notified that the gun is "Ready." If to this degree of skill and excellence of mount is added a firing mechanism in such thoroughly efficient condition that the gun will fire with certainty at the earliest possible moment after the pointer wills to fire, the rapidity of *aimed* shots is made practically to equal the rapidity with which *unaimed* shots may be fired. So long as this degree of rapidity is possible with any gun, it is evident that any time which elapses between the word "Ready," and the firing of the gun is a clear loss, and its cause must be due either to—

(1) The lack of skill of the pointer in not having his gun accurately aimed before the word "Ready," or,

(2) The inefficient condition of the mount, or of the firing mechanism which prevents him from pointing and firing the gun with facility and certainty.

General Remarks on Naval Gunnery.

19. From the above it is apparent that skill in gunnery—measured by the rapidity of hitting the point of aim—depends not on

the pointer alone, but on every person actually participating in the practice; on the gunnery officer, in case he is controlling the fire of the ship, on the division officer, the gun-captain, both pointers, the sight-setter, and on each individual member of the gun-crew.

20. The greatest rapidity of hitting can be attained only by the united efforts of each person concerned, working as in an athletic team, in complete harmony with every other member of the crew. A failure in the slightest detail on the part of any one participant may materially reduce the rapidity of hitting, and thus nullify the greatest possible excellence on the part of the others.

21. In the following epitome of the duties of the various persons participating in the firing of a great gun, attention is confined to the gun-crew as a fighting unit. Whether one gun, or all guns, are firing, whether the ranges are determined by the division officer himself, as in record target-practice, or are transmitted to the divisions by the gunnery officers, the range and lateral compensation are given to the sight-setter by the division officer (or by some person appointed to assist him in doing this), and the duties of the members of the gun-crew remain in all cases the same.

The Division Officer.

22. It should be the division officer's ambition to obtain from each gun in his division, at each practice, the greatest number of hits per minute possible with his particular types of guns. Having trained his division to this degree of excellence, it is ready to be used as a unit by the senior officers of the ship in the more advanced fighting efficiency practices, simulating action, in which all divisions of a ship are exercised together with a view to bringing the ship itself to its highest degree of excellence as a unit of the fleet. It is evident that until the subdivisions of a ship's force (the gun-divisions) have attained a high degree of individual skill, it would be fruitless to attempt to develop a high degree of excellence in the ship as a whole. Therefore a division officer's chief duty is the development of his gun-division, which in turn requires the development of each individual gun-crew in it to the highest possible degree of excellence, and then to use this division

to the best advantage as a unit, in the exercises for the development of the efficiency of the ship. In training his division up to a high degree of excellence at record practice, there is not a single feature of naval gunnery, as enumerated above, that a division officer can afford to overlook or neglect. Guns, gun-crews, ammunition, and the necessary authority are given to him, and with these he is expected, after a limited period of training, to hit the target rapidly.

23. The duties of a division officer in connection with great guns naturally divide themselves into two classes:

(1) Duties necessary during the course of training prior to target-practice.

(2) Duties necessary during target-practice.

24. Duties prior to target-practice.—These may be divided into the headings:

(1) The acquirement of a thorough knowledge of, and the maintenance of, his ordnance material in perfect condition.

(2) The intelligent training of his gun-crews.

25. Knowledge of, and maintenance of, perfect condition of ordnance.—The very best results can be attained only by an officer who has a thorough and complete practical knowledge of all of the ordnance material under his charge. This does not mean a general knowledge of how the guns and appurtenances are rigged and used; it means the most complete knowledge, especially practical, that it is possible for him to obtain. Needless to say, he should know more about every detail of his guns, mounts, sights, ammunition, or other ordnance supplies, than any other person in the ship. He should ascertain and record the initial velocity for which each of his sights are graduated; the kind and amount of powder required to give this initial velocity; the normal pressure; the pressure to which the gun has been tested; the length of the gun in calibers; the permanent angle of the sight, etc. He should construct for each gun a table showing, for the various ranges:

(1) The angle of elevation.

(2) The angle of fall.

(3) The time of flight.

(4) The "danger space" for 19 feet (the height of the top of the target).

(5) Drift remaining uncorrected.

(6) The lateral distance corrected by one division on the sliding leaf.

(7) The lateral effects of the apparent force of winds of various strengths on the projectile.

(8) The vertical distance at various ranges, corresponding to changes of 100 yards in the sight-bar.

(9) The effect on the trajectory of a variation of 1 per-cent in the density of the air.

26. He should render himself thoroughly familiar (both practically and by a study of descriptive pamphlets, or other literature) with the construction, use, and means of manipulation of every piece of the mechanism of the gun, mount, or accessories. He should thoroughly familiarize himself with the regulations for the care, preservation, and precautions to be observed with the ordnance outfit, and should assure himself that these regulations are strictly observed by the members of his division. He must assure himself by frequent inspections that the ordnance and all appurtenances under his charge are always kept in the most efficient possible condition; and if the guns and mounts do not then work with the required facility, it is his duty to take such steps toward their modification as will insure their efficient operation. He must see that the sights are, when at point-blank, in adjustment with the bore-sights, and not only that they are maintained in as good a condition as when supplied, but also that they are sufficiently secure to withstand the shock of discharge without jarring out of adjustment. Similarly, he must see that his firing connections are strong, and well secured; that the firing mechanism and the batteries are in efficient condition, and that the circuits are complete.

27. Immediately before a target-practice, he should critically examine all ammunition that is to be used, and should assure himself of its perfect cleanliness, good condition, and when practicable (by actual trial in the gun), of its proper size. In all practices, faults in any of the above mentioned items seriously retard the rapidity of fire, and very seriously detract from the efficiency of the division. All delays in firing, caused by faults such as

weakness of lanyards, raising burrs, sights out of adjustment, etc., or delays caused by the inherent weakness or delicacy of any device or appliance which has been duly supplied, but the weakness of which could reasonably have been anticipated and remedied by the force on board, are considered faults of the crew, and time occupied in their rectification during a string of shots, counts against the crew. In such cases, the fault clearly lies with the division officer.

28. The intelligent training of his gun-crews.—To train intelligently the crews of the various guns to the highest degree of efficiency, the division officer must himself know each individual duty of every member of the gun-crew, and how such duties can best be performed. He must, in all exercises with the various devices for training the gun-crews, as well as at actual drill at the gun, insist on the careful observance of all of the minor details of the drill, bearing in mind that any drill that is carried out without observing every detail which it would be necessary to observe in actual firing, or without striving to attain as great a degree of rapidity as will be sought in target-practice or action, *is actually detrimental to the gun-crew.*

29. Owing to the number of gun-crews which may be under the command of one division officer, each officer should consider as a most important feature of his own duties, the development of the gun-captains of the various guns so that they can efficiently drill and, so far as necessary, instruct their own gun-crews.

30. Duties during target-practice.—Assuming that the above duties have been efficiently performed prior to target-practice, the score made by the division, or by any single gun-crew, depends as much on the efficiency displayed by the division officer in the performance of his duties during target-practice, as on the efficiency of the pointer, or any other man in the gun-crew. These most important duties are:

(1) The accurate determination of the distance of the target at each particular instant during the actual firing.

(2) The display of care and judgment in applying to these distances, corrections based on the observed fall of the shot.

31. The data obtained by the observation of the fall of the first shot of a string should be adequate to insure the remainder of the

shots hitting the target, provided the pointers are well trained, the ordnance in good condition, and the division officers well informed as to the trajectory of his gun.

32. Duties of division officers in small-arm practice.—Small-Arm Firing-Regulations fully explain the general duties of the division officer in connection with this form of practice.

(1) The division officer is responsible for the strict observance of all regulations laid down for the safety of the men of his division and of other persons who may expose themselves while firing is in progress.

(2) He should see that all regulations are strictly obeyed, and he should attempt to bring his division to a high degree of efficiency in all of the prescribed methods of firing. He should seize every opportunity to carry out the supplementary forms of practice which are permitted, though not absolutely required by the regulations.

(3) In all "instruction practice" he should bear in mind that the purpose is to *teach his men the correct methods,* and to *teach them the art of using small arms* to the best advantage; not to obtain the highest possible score.

Turret-Captains.

33. A turret-captain, as the name implies, is second only to the officers, in his authority in a turret.

(1) This position was created in order that our turret-crews might be so organized that their efficiency in action would not depend too much on the presence of the officer of the turret; that is to say, in order to provide some leading man in each of our turrets who could be relied upon to perform the vitally essential duties of receiving orders, adjusting sights, directing the setting of sights, and particularly who could be trusted to carry out the very important regulations in the drill-book for insuring safety in all operations during loading, firing, or in the case of missfires, hangfires, or unforeseen casualties.

(2) In his daily duties the turret-captain is charged with the care, preservation, and efficient condition of everything belonging to the turret to which he is assigned. He should give the neces-

sary orders to the captains of the respective guns and ammunition crews, or to the gunners-mate of the turret as the case may be. He will see that such orders are promptly executed, superintending and assisting with the work as may be necessary. Any duty in connection with the turret devolving upon the gunners-mate, or the gun or ammunition crews, whether repairs, cleaning, overhauling, general work, or drill, is under his general charge, and he is responsible to the turret-officer for the efficiency and thoroughness thereof.

(3) In the absence of the turret-officer, the turret-captain assumes charge, carries out the regular drills, the training with mechanical targets, actual target-practice, or commands the turret in action in the same manner as the division officer would do were he present. In addition to the knowledge and ability necessary to drill the turret-crews and, in the absence of the turret-officer, to direct the fire of the guns in action, the turret-captain must have the mechanical knowledge and ability necessary to overhaul all parts of the turret and gun-gear, and to keep them at all times in efficient condition. His general duties are, therefore, such as to render it indispensable that he acquire a thorough knowledge of the ordnance of his turret, and he should make every effort to obtain and read the detailed instructions describing the various features thereof.

Gun-Captains.

34. Each gun-crew has a gun-captain, who besides his duty in his individual station at the gun is in charge of that gun and gun-crew.

(1) During all drills and exercises with the gun, the gun-captain must be in a position to superintend and direct the movements of the members of the gun-crew; for this reason he is not stationed as pointer (except in guns of the secondary battery), nor can he ever become the pointer so long as he remains gun-captain. He can generally best perform his duties as gun-captain when stationed as plugman. The fewer men in the crew of a secondary gun, together with the position of the pointer in the rear of the breech, enables the pointer of such guns to act as gun-captain.

(2) A gun-captain must not be allowed to regard his duties as

merely perfunctory. He receives extra pay to act as captain of that gun and gun-crew, and he has the same relation to his gun and gun-crew as a coxswain has to his boat and boat-crew. He is responsible to his division officer for the care of his gun, and for the drill of his particular gun-crew.

35. While his duties in the instruction and development of his crew have to do very much more with the development of its practical skill in serving the gun, than with its theoretical instruction, he should be thoroughly familiar with his gun, mount, and appurtenances, and be able to explain such essentials to the crew as will enable them to gain the best practical results from their exercises. He has immediate charge of all of the exercises with the mechanical devices provided for training the crew, and should therefore clearly understand the purpose, and the object to be attained by each exercise As he is responsible to the division officer for the practical development of his crew, he should always bear in mind that it is his duty to get the very highest performance out of the crew that it is capable of. The principle cannot be too strongly impressed upon either gun-captains or gun-crews that every movement at gun-drill should be made *quickly,* no matter how much time may be then available. This is always necessary at gun-drill because the gun-crew is being trained for the one great emergency of battle, and at such a time every second, every fraction of a second counts; and the only way to obtain a gun-crew which will utilize advantageously every fraction of a second in battle, is to train it to do so in time of peace. When the crew is finally engaged in actual battle, it should be so accustomed to using intelligent speed at drill that it will then do so *mechanically.* Every instant saved in action increases the "hits per minute;" to save instants in action, the crew must be *trained* at saving these instants beforehand. In other words, the crew must be *trained at rapidity of fire,* rather than simply *instructed in it,* and every effort of a gun-captain should be directed to that end. It should at all times be remembered that drill is but a preparation for action. Never for a moment permit slouchiness, or inattention on drill. If a crew is permitted to drill slowly or carelessly, it will do so in action unless it is *then made to hurry,* and on being *suddenly hurried* true rapidity will not be attained. Remember

always, that a drill is as much for the purpose of instructing men how to serve a gun *quickly,* as how to serve it at all.

36. For the purpose of assisting in the training of gun-crews, a certain course of training has been prescribed for pointers and gun-crews. The gun-captain has the immediate supervision of these exercises, and should see that they are at all times carried out in accordance with the instructions, otherwise the best results will not be attained. An efficient gun-captain will, therefore, have:

(1) A thorough practical knowledge concerning his gun, mount, accessories, ammunition, etc.

(2) The ability to take charge of, drill, and instruct his gun-crew in practical details concerning his gun, without the supervision of an officer.

(3) The executive ability to handle a crew of men, make them perform every detail of the drill, and maintain their parts of the gun and mount in excellent condition.

Gun-Pointers.

37. The gun-pointer group consists of the first and second pointer, and the sight-setter, and each of these men must be carefully trained to acquire skill in accuracy and rapidity of pointing. A gun-pointer must remember that he has a most important position. A ship is built for the purpose of using her guns, and therefore the pointer is a man of vital importance to the ship. A ship may never be engaged in action more than a few minutes during her whole career, and if in this few minutes a pointer, through over confidence or neglect of any of the details of training, fails to fire accurately or as quickly as possible after the gun is loaded, he fails in his duty to his ship in that he has occupied one of her important positions of offense without doing the enemy the greatest possible injury.

38. Pointers must not, however, misunderstand their duties. It is a pointer's duty to fire the gun as soon after it is loaded as he can get his cross-wires, or his line of sight, to bear accurately on the *middle* of the target, or on the portion of the enemy that may be designated as the point of aim. He has nothing to do with the correction of his sights: that is done by the sight-setter

under the orders of the division officer. In all cases the pointer must aim exactly as he is directed, otherwise nothing can be determined from the fall of the shot, and corrections made by the division officer, based thereon, will be erroneous.

39. The firing-pointer must control the pointing of the gun. The training-pointer will keep his sight set roughly for the range, but exactly for the lateral compensation ordered, and, unless otherwise directed by the firing-pointer, will keep the gun trained continuously on the center of the target. If in the opinion of the firing-pointer, the gun is not trained exactly "on," he will give the orders "right," "left," or in the case of an apparently moving target, "a little faster" or "a little slower," and the training-pointer must obey the command even though he thereby throws his own sight off. Both pointers will, at all times, keep their eyes pressed firmly against the rubber guards on the eye-pieces of the telescopes, and keep the cross-wires or the line of sight constantly on the target when it is practicable to do so.

40. Skill in pointing is shown in *bunching the shots* when the sights and the points of aim remain unchanged. If a pointer, firing under the orders herein laid down, bunches his shots in a small area when the sights remain unchanged, it shows that he is a skillful pointer whether the shots hit or miss, as it is the duty of the division officer to order the alteration of the sights so as to bring the bunch on the target. A bunched string of shots simply shows that the pointer aims alike each time, and fires each shot at the same corresponding moment in each roll, and if he does this, and does it quickly, it is all that can be required of him. The division officer must do the rest.

41. Skill is required to point the gun in exactly the same manner for each shot, and especially is this the case when the ship is rolling or pitching. In this case the fall of the shot will be so affected by the motion of the ship, that an inexperienced and untrained pointer cannot hit the target. If the wires are "on" when he makes up his mind to fire, they are "off" when the projectile leaves the gun, and in such cases he will fire over, if the ship is rolling away from the target, or short, if rolling towards it. This, the greatest error of naval marksmanship is avoided (1) in heavy guns, by training men to allow for the "fir-

ing-interval," that is, to judge correctly the proper moment to fire so that the wires will be " on " when the projectile leaves the gun; and (2) in all guns capable of doing so, by keeping the wires " on " during the " firing-interval," so as to eliminate the effect of the roll. Much skill and constant practice are essential with either method.

42. The quickness with which a pointer can aim and fire his gun is a most important factor in his excellence, but a pointer should always remember, in his zeal for rapidity, that if the wires are not *exactly* " on " when the projectile leaves the gun he will surely miss, and he will have actually thrown away the entire time required to load, aim, and fire that shot; therefore accuracy must never be sacrificed to rapidity.

The Sight-Setter.

43. The sight-setter must keep the sight set exactly as he is ordered (both the lateral and the vertical setting being done by him), and he must keep the training-pointer notified as to how the firing-pointer's sight is set. He must carefully watch the sight during firing to see that it is not jarred out of adjustment by the discharge of the gun. He must realize that unless at each shot the sight is accurately set, the pointer must certainly miss. This most important element in accuracy of fire is too often neglected, the pointer having almost invariably a disposition to correct small changes of range, or small errors both vertically or laterally, by altering his point of aim. This is now absolutely forbidden, therefore all the greater care is required of the sight-setter and division officer. As previously stated a good pointer will bunch his shots somewhere, if he aims always at the same place. While this is all that can be required of the *pointer,* it is not enough for the *gun;* the gun is for the purpose of hitting the point of aim, therefore when the gunnery or division officers observe that the shots are being bunched *off the target,* the range and lateral correction are so changed that the shots are made to hit, the pointer continuing to aim at the same point as before. If, when a change of range or lateral correction is ordered, the sight-setter does not promptly and accurately set the sight to conform

thereto, he may be, himself, wholly responsible for a series of misses. It should be borne in mind that when sights are not correctly set, the more expert a pointer is the less chance he has for hitting, because *were he a perfect shot he would* NEVER *hit the point of aim with sights which were incorrectly set.*

44. While the amount and direction in which to move the sliding leaf will always be given to the sight-setter by the division officer, it is important that both the gun-captain and the members of the gun-pointer group thoroughly understand the direction the sight must be moved to correct errors made. The rule is so simple that every one can understand it. It is simply necessary to remember that the shot always falls in the direction the rear-sight (or the eyepiece of the telescope-sight) is moved. Everyone knows that if we raise the rear-sight, we fire higher; if we lower it we fire lower; similarly, if we move it to the right we shoot further to the right, and if to the left we shoot to the left.

Rapidity of Loading.

45. Having now considered the pointing and sight-setting, the rapidity and precision of serving the gun follows.

(1) No pointer can make a high score in hits per minute unless the gun-crew is capable of continuous rapid loading; and no gun-crew will be capable of loading a great number of times in a minute unless the members of that crew have been trained, as a team, to do their individual duties quickly, thoroughly, and in such a manner as to in no way interfere with each other.

(2) Gun-crews, when at drill, are too apt to regard small matters as of no consequence, but these are always the causes of the delays when it comes to actual firing. Therefore every small detail in the gun-drill should be zealously practiced by each member of the crew.

(3) Every man should feel that in practicing the small details that are mentioned in the drill-book, he is learning to avoid what some one else learned by actual experience.

Summary.

46. Summarizing the above instructions:

(1) *Turret-captains and gun-captains* have complete charge

of their guns or turrets under their division officer, and their knowledge should be such that they can in action, drill, or target-practice, efficiently take the position of that officer in controlling the exercise or fire from their particular gun.

(2) *The pointer's* sole duty in firing is to keep the cross-wires as constantly on the target as possible, and to fire as soon after the gun is loaded as he can hold them accurately "on." He should be oblivious to his surroundings, as his only duty is to point and fire the gun. He has nothing to do with correcting the errors made through incorrect sight-setting, except when no sliding-leaf is provided, in which case he must alter his point of aim as directed by the division officer.

(3) *The sight-setter* watches the sight constantly to see that it remains at the correct position; alters the setting of the sight as ordered, and keeps the training-pointer informed as to the correct setting of the sight.

(4) The other members of the crew must, by careful attention to the details of the drill, attain the greatest rapidity and precision of loading, which is only to be acquired by constant training as a team.

(5) Those members of the crew concerned should observe the following rules:

(a) Use every effort to gain the maximum rapidity of hits.

(b) After the gun is loaded, fire the first time the cross-wires bear accurately on the target, provided it is possible to hold them "on" momentarily.

(c) Never fire a gun when the sights do not bear accurately on the target.

(d) Whatever any member of the crew has to do in serving a gun, *do it thoroughly,* and time will be saved in the long run.

Ordnance Duties of Junior Officers of Divisions.

47. When midshipmen graduate from the Naval Academy, and go out into the service, they are, in addition to their watch and other duties, assigned to duty, sometimes in charge of divisions on small ships, but usually as junior officer of a division on a large ship.

48. During the course at the Naval Academy, midshipmen have received instruction in all of the theory of ordnance and gunnery that will be of practical value to them in their sea-going duties in the future, but owing to the lack of time and facilities, their instruction in practical gunnery has necessarily been of an elementary character. They have been instructed in the principles of straight shooting; have been drilled at certain classes of guns, and are familiar with the use and advantages of the various devices for the training of gun-pointers and gun-crews, but owing to the scope of this subject of practical gunnery, owing to the continual changes and improvements in naval ordnance, and to the lack of opportunities for more practical experience, midshipmen, in going out into the service, must realize that they are yet under instruction, and have much to learn, the main difference being that while they are at the Naval Academy they are taught, drilled, and made to recite to their instructors—information being thus placed in their hands—whereas, after graduation, they must study for themselves, and often obtain the desired information only after much research. Before graduation their failure to understand a subject, only affects their recitation or examination; after graduation a lack of knowledge on practical professional matters subjects them to chagrin in exposing their ignorance before the men of their division, whom they are supposed to instruct; it affects their reputation as officers, and it diminishes the efficiency of the ship on which they are serving. If the midshipman happens to be detailed as the officer in charge of a division before he has had experience as a junior officer, with little opportunity to practically learn the duties of a division officer, it is the more necessary that his effort to learn all of his practical duties be diligent and absolutely thorough; for on him alone will rest the responsibility for the efficiency or inefficiency of the division, the merit of which will be clearly shown at the first record practice.

49. The primary duty of any division officer is to develop his division as a whole, by drill and instruction, so that it can efficiently perform any of the various duties required of it. The various drills which the divisions have on board ship are for the purpose of perfecting them in each of the exercises, in order that under actual service conditions they can perform these duties effi-

ciently and without further instructions at that time. It is, in short, so that the division may be maintained at all times ready for any service which it might be called upon to perform were a war to break out immediately. This point is frequently lost sight of by young officers. It should always be remembered that the final test of the efficiency of a division is a consideration of the question "If action were imminent, would I desire the division to be more proficient?" If the answer is "yes," now is the time to add to its proficiency. Knowledge is valuable only for its power to produce results. In divisional duties, the entire object is to do practical things, not to teach theory. Practical knowledge of a most detailed kind is necessary to an officer to insure his gaining the highest possible practical results from his division. The standard of excellence in each division, boat-crew, or gun-crew, is not how much they know, or how well they are instructed in the performance of their duties; it is how well do they *perform* the duties which are required of them; and the nearer a division approaches perfection in its actual drills, the nearer have the officers in that division succeeded in the perfect performance of their duties.

50. No person can efficiently drill or instruct others in any subject unless he himself knows thoroughly and accurately every detail of the drill or the matter under consideration; therefore after reporting for duty on board a ship, the midshipman should at once prepare himself for his divisional duties by thoroughly informing himself on every detail concerning the division to which he is assigned, whether he is in charge or junior officer of it. He should realize that he is now an officer, and that he will be so regarded by both the officers and the crew of the ship, and that so long as his knowledge of every detail of matters under his cognizance is not greater than that of any man of his division, just so long will he fail to command the highest respect from his men.

51. A midshipman should, therefore, immediately after reporting for duty, begin diligently to inform himself on all matters pertaining to his own duties, the duties of his division, and of each individual man in it. He should make out a copy of a complete watch, quarter, and station bill of the division to which he is assigned. This should show the individual duties of each member

of the division at general quarters, fire, collision, boat, company, and landing drills, as well as the cleaning station of each man. If he is to be the junior officer of the division, this bill should be copied from his division officer's station bill; if he is to relieve some other officer in charge of a division it should be obtained from that officer in order to avoid any unnecessary changes in the stations of the men. If he can obtain it in no other way, it may be copied from the ship's station bill, but this will not show the individual duty of each man at each exercise. He should as quickly as possible become acquainted with each man of his division, learning their names and rates, their personal characteristics, their individual value and degree of reliability. He should acquire a thorough detailed knowledge of the position of the ordnance and appurtenances supplied to his division; learn the location of the magazines, ammunition-hoists and scuttles, pumps, hydrants, fire-hose, tarpaulins, hatches, etc., within the limits of his division, and by visiting the part of the ship in which his division is stationed, preferably with the division officer or with the officer whom he is to relieve, familiarize himself with each duty that the station bill requires his division to perform, so that at the very first drill he may intelligently perform his duties as an officer. He should, in brief, as quickly as possible, render himself familiar with every detail connected with his division and the duties which it has to perform, and as a test of his proficiency in this respect, he should run over in his own mind the duties of his division at the various drills, and ask himself if he is competent to perform the duties of each man at each drill. An officer cannot be proficient in his divisional duties until he is competent to do this.

52. A thorough detailed knowledge of the guns of his division, their mounts, accessories, firing mechanisms, and ammunition, as well as a detailed knowledge of the drills, practical notes in connection therewith, the place where each article required at drill is stowed, and the exact duty of each member of the gun-crews is an absolute essential. He should therefore make a careful study of all available literature descriptive of his guns, mounts, ammunition, etc., as well as all instructions concerning the care, preservation and manipulation of his guns. Instructions for

training gun-pointers and gun-crews, and for conducting target-practice, should be matters of perfect familiarity with him, and he should as soon as possible render himself familiar with the current orders of the ship, by reading the Captain's and the Executive Officer's order books. As the primary duty of any division is the effective use of the guns of the ship, the details of the duties above given for both the division officer and for each member of the gun's crew are matters of extreme importance to him, and should be strictly observed.

53. As junior officer of a division, a midshipman is the assistant of the division officer, and he should by observation of that officer, attempt, in all practical details, to profit by his more extended experience; a midshipman should endeavor to make his manner of carrying out the drills and exercises, and his general method of handling the men of the division, conform as nearly as possible to that of the division officer, and he should evince as great an amount of zeal in the progress and efficiency of the division as he would do were he himself the division officer. All instructions governing the division officer, apply with equal force, except when clearly inapplicable, to the junior officer of the division.

54. After having thoroughly acquired and mastered all information concerning the duties of his own division, the midshipman should then, like any officer on first joining a ship, devote himself to a study of the details of the entire ship. He should, however, never allow this, which may be regarded as *general information,* to in any way interfere with an absolutely thorough knowledge and performance of his duties in his own division. This is his primary duty; this is where he is stationed; and this is the division which he is responsible for developing.

55. The daily divisional duties of a junior officer will, of course, be as required by the division officer, but the following may be laid down as general rules:

(1) The junior officer of a division should always be present during the period assigned to cleaning gun bright-work. He should see that all men who are not excused are present, and that those who are present clean all of the bright work of the gun, in-

cluding that usually cleaned by those who are excused or who are necessarily absent. In the performance of this duty he should, so far as practicable, give his orders only to the captains of the various guns, and should require them to supervise the cleaning of their individual guns, and to detail the individual numbers who are to clean the bright work of the absentees.

(2) *At morning quarters* he assists in forming and inspecting the division, as required, accompanying the division officer throughout the inspection. While at quarters during the temporary absence of the division officer, he takes command and sees that order is preserved.

(3) *At drills* and at all exercises he should be diligent in requiring the performance of every single detail. At any time when the division officer is absent, the junior officer succeeds to the performance of all of the divisional duties.

56. If a midshipman is detailed as junior officer of the Engineer or Powder-Division, his general duties are similar to those above described. His first duty is, in every case, to make himself master of the situation by thoroughly informing himself on every point which falls under his charge, including not only the mechanical arrangement and details of the mechanism in his division, but also of all ship and naval regulations governing his duties, of the customs of the ship, the customs of the service, etc. In whatever capacity an officer may serve on board ship, his duties are laid down in a general manner in the U. S. Navy Regulations, and adequate information on all professional matters are available to him; ignorance of regulations is never an adequate plea for inefficiency.

57. Therefore, to whatever duty a midshipman is assigned, he should remember that his value, reputation, and ability will depend on his knowledge of his profession, his attention to his own duty, and the exactitude which he requires of his subordinates in the performance of their duties.